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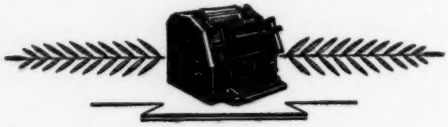

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THE ALUMNI SHOULD KNOW

The engineering faculties of our colleges and universities have studied the Report of the Investigation of Engineering Education and have answered many questions they had asked and which alumni have asked and will continue to ask but we have not fulfilled our entire duty of interpreting to the alumni the results which the careful consideration of the reports have produced. Should we not inform our graduates more fully through our alumni publications?

First, in dealing with the alumni, both they and we take too much for granted. They often think of curricula and methods as being the same as they were ten or twenty years ago. In the main they are but in detail they are different.

There have been changes in curricula. What are they? Why were they made?

Changes proposed by graduates have not been adopted. Why? Because the tendency is away from specialization or because the suggested subject is essentially postgraduate or for other reasons. If we expect the alumni to continue their interest in engineering education, then the general conclusions of such a survey should be interpreted to them.

Has economics been included?

If subjects have been added related to humanics, industrial relations, management, would it not be interesting to state why and the purpose of the course or courses?

Is special provision made for the exceptional student? Have courses in public speaking been added? What other improvements in courses, laboratories or staffs have been made?

Secondly, we assume that they know the changes which have taken place. How will they know, if we do not keep them informed?

The interpretation of the Investigation gives us a prime opportunity to draw them closer to their Alma Mater and to the engineering school or college by a frank discussion of progress made. Incidentally we review the report again in order to give them a digest of it and that is good for us also.

More important than either, alumni are assured that we are neither asleep nor indifferent to their suggestions. They are busy men, keen to appreciate evidence that their institution and their profession are alert to advance abreast of industry (or in advance) and are intelligent in weighing real as opposed to spurious advancement.

R. L. SACKETT,
Dean of Engineering,
Pennsylvania State College.

THE FUNCTION OF RESEARCH IN ENGINEERING EDUCATION *

By DUGALD C. JACKSON

Massachusetts Institute of Technology

"... to sift the grain from chaff,
Get truth and falsehood known and named as such."

More than thirty-five years ago Dr. Robert H. Thurston, then Director of Sibley College, was a guest at the University of Wisconsin where I was a youthful and rather new member of the faculty trying to build up suitable laboratories of electrical engineering with inadequate funds. We had much extemporization by teachers and students in the use of equipment. This brought to the surface the peculiarities of each piece of apparatus used in unusual relations, and we were having a grand time experimentally determining the reasons for various observed phenomena which hitherto had not been fully explained. Dr. Thurston walked about our few and meagre machines while I told him what we were doing with them and how they served as elements of student work. Then he simply remarked that he was pleased to find us "carrying on so much research".

I confess that this remark of his struck me with rather profound surprise and the impression that it gave me is still rather vivid. We (the teachers and students in electrical engineering) were testing and investigating various strange or unfamiliar effects, but this was all in course of satisfying our curiosity regarding unexplained features of the instrumentalities in our field of engineering life. I presume that none of us had thought of it as "research". Research at that time rested in my mind as something leading up to a multiple volume treatise like Faraday's "Experimental Researches", Maxwell's "Electricity and Magnetism" or Helmholtz's "Sensations of Tone"; or perchance culminating in revolutionary discovery, like Faraday's researches in electromagnetic induction or Newton's investigation of motion and gravitation. Our activities were simple investigations carried on to satisfy enquiring minds and executed in the daily life of a group of students preparing themselves for their professional work. If these activities were re-

* Presented at the 39th annual meeting, S. P. E. E., Purdue University, June 17–19, 1931.

search, it seemed an inevitable conclusion that research is a part of engineering education. The conclusion is sound. Research not only has a function in engineering education, but it is more—it is an integral part of properly conceived engineering education.

The recorded early part of the lives of Michael Faraday, Joseph Henry, George Stephenson, Alexander Holly and a host of others to whom we are indebted for the present status of engineering and the engineering industries shows plainly that the principal quality of their education, which primarily was self-education, arose from just such activities as were characterizing the electrical engineering laboratories in the University of Wisconsin to which I have referred. It was truly education to such men—in some instances almost the only education they secured in youth; it also was research of moderate order, and Dr. Thurston was right in dubbing as research the activities going on in our Wisconsin laboratories.

However, I prefer to call such rudimentary or elementary research an exercise of the spirit of enquiry or scientific curiosity, and make the latter a definite feature of engineering education, to which it pertinently belongs. Phenomena and their interrelations command the engineering life, which is thus distinguished from the more arithmetical life of a merchant-prince or a country banker. Enquiry regarding phenomena may be analytical in character, calling for pencil and paper. It perchance may be philosophical in nature calling for argument or debate. But such enquiry is most fruitful when originally unfolded in the laboratory, or the validity of its analytical or philosophical conclusions have been tested there. The laboratory of physical experiment is an eminent aid to the analytical and philosophical enquiries by affording pragmatic tests of the soundness of original analysis or philosophical synthesis, besides also of itself being a place for original discovery. Words alone are not enough. The individual must exercise the habit of seeing and investigating for himself.

Joseph Henry at one time nicely stated in words one of those platitudes that ought to be commonplace elements of every engineering teacher's processes, but too often are forgotten because they are only platitudes: "There is a great difference between reading and study; or between the indolent reception of knowledge without labor, and that effort of mind which is always necessary in order to secure an important truth and make it fully our own." The crystallized hindsight of the printed textbook page and the conventional classroom lecture do not alone stimulate most minds to the necessary effort; but a ready instrument for such stimulation lies in the practice of investigation carried out under sympathetic counsel and direction by suitable leaders. For sufficiently ad-

vanced students the seminar consisting of a student group, carrying on research under the guiding influence of lectures by a professor, mutually discussing their inferences and conclusions, also perhaps testing them in the laboratory, and writing dissertations summarizing results of their enquiries, is a practice of proved success in higher education.

This is an age when most intellectual individuals prefer to command a great project than to inscribe a Greek verse, and this mental attitude has brought large rewards to the common people of the world as well as to the individuals who have dared on their behalf to deal with Nature in new ways. The fine arts and the decorative arts lose no distinction by sharing their pedestal with the products of creative-minded men who concentrate their attention on those things that contribute to the physical welfare of the human race. Indeed, this sharing has brought to the graceful arts an incense of appreciation which has steadily broadened without sacrifice to its depth. The scientists and engineers lead the van of the daring ones, but none will "dare" except he possesses an investigatory spirit and a resourceful mind. If formal education is to do much for such men in their youth, as we claim is a prime object of engineering education, the education must be directed to research of the varieties that encourage the spirit of enquiry and add to the store of intellectual and manipulative resource. Lacking this, our disciples will not be among those who lead in the conquest of unknown regions and marginal areas that face the engineering industries--which conquest may decade by decade confer yet larger and more widely spread benefits on the common members of the human race. Book learning, and instruction about facts of Nature and Man, are a background for stimulating intelligence and arousing ambition, but alone they are static and insufficient to stiffen the students' back-bones and inspire them to balance initiative originality and self-reliance.

The boon of such stiffening and inspiration, along with lessons in the joys of accomplishment, may be conferred on our students by leading them into the paths of research, minor and easy paths at first but becoming more excitingly difficult according to the advancement of each student. The achievement of this process is difficult. Nevertheless, experience shows that the effort is worth while and observation indicates that the greatest centers of engineering education have become great and attractive to ambitious students because of willingness in those centers to make the effort.

Such reflections are fully supported by experience and observation. They may be verified by examples. The department of electrical engineering at the Massachusetts Institute of Technology and the like department at Cornell University share the honor of

directing the earliest established formal curricula in electrical engineering. The world's practice in this field has largely grown from these two examples. These early curricula were both established in the academic year 1882–3, one late in 1882 and the other early in 1883, and students in each first received degrees in course in June, 1885. In those days the action of electrical machinery was not altogether understood and often was crassly misunderstood; the characteristics of electric circuits under transient conditions had not been extensively explored; equipment was meagre; instruments for measurement were inadequate; textbooks were not available; and instruction, as a matter of necessity, was by the seminar type of study and investigation carried on by students under direction of the professors. Some lectures were provided but mostly the students studied the character of machines, instruments and circuits in the laboratories and reflected on the possibilities and consequences of modifications. Much extemporization was exercised to demonstrate the results of changes in combinations. If a machine or device was lacking and could not be borrowed in some form, students made it. The data for complete mathematical analysis were lacking, and the possibilities of many forms of analysis now in common engineering use were only showing over the horizon as an absorbing stimulus to individual ambition and study. The setting was one of vital and wholesouled intellectual interest. Examining the rosters of men who were in the early classes of these two courses discloses a notably high proportion of their members who became of high place in electrical engineering.

At a somewhat earlier date President Morton, Professor Thurston, Professor De Volson Wood and their associates at Stevens Institute of Technology were developing a similar situation in mechanical engineering. In that period Professor Thurston established a laboratory for investigation in the engineering sciences. Nowadays we would call it a research laboratory. These men were trail breakers in mechanical engineering education, and it may be significant that the roster of early graduates of Stevens now reads like a "Who's Who" in Mechanical Engineering. The influence of those graduates during the unfolding of American industries has been tremendous and magnificent. Still earlier, a devoted group at Rensselaer Polytechnic Institute worked through a similar development period in civil engineering education; and the large influence ultimately impressed by their students on American engineering is sufficiently well known.

These examples are typical and selected without overlooking the meritorious results from other early engineering schools and curricula established in the last half of the nineteenth century. Perhaps the interesting influence in chemical engineering of the courses

of study in that branch that came into being a quarter of a century ago, or thereabouts, partly arises from a similar set of conditions growing out of applications of science in newly growing industries, which stimulated enquiring minds and led instruction through the paths of investigation.

Many of our present students will be inspired to mature performances just as notable as those of their predecessors, but can we unqualifiedly assert that those thus achieving will comprise an equally large proportion of the present generation of students as in the examples above referred to? I think that it is generally agreed that the answer to this question is No. It may be lightly commented that now there are more students in the engineering schools and that they are less ambitious and scholastically less well prepared to pursue their courses of study in engineering; but this is not a sound rebuttal. There now are more engineering schools and many more professors employed in them, compared with the numbers at the close of the nineteenth century. Are we ready to concede less intellectual vitality, devotion and ability in the individuals of our group of teachers than in the corresponding group of forty years ago? That would be an ignominious confession. In my opinion there is as much intellectual vitality, devotion and ability per unit in our group today as there was forty years ago. The information disclosed in Vol. I of the Report of the Board of Investigation and Coördination of this Society supports the opinion:

"The educational standards of the present group of engineering colleges taken collectively compare favorably with those of all other equally comprehensive groups of undergraduate colleges. This statement holds for the adequacy of their physical facilities, the number and qualifications of their teachers, the level of their admission requirements, the content and rigor of their curricula, the soundness of their scholastic standards, the extent and quality of their research activities, and their expenditures per student."

I will add the comment that an investigatory spirit and achievement are more important attributes for the engineering teacher than higher degrees, and we must fix our faces unwaveringly against a policy, now somewhat established in the colleges of arts, of making staff appointments from Doctor's Degrees attached to second rate men in preference to selecting first rate men without the doctorate when the first rate man cannot be secured along with the doctorate. The man without fire in his soul is of little value as a teacher of engineering even though he may have good industry. The man with neither fire nor industry is but loss in this occupation. Even where location and means preclude formal organization of research, this character in the teaching needs be kept foremost in

the minds of the teachers. The opportunity for its exhibition is not lacking in any of our properly administered engineering schools. It should be the object to saturate our students in an aura of resourcefully productive thinking and doing. Plenty of this aura must emanate from the spirit of those who teach the classes, to be effective on the students; and not be the outcome alone of those who direct departmental affairs or those who confine their endeavors to formal research.

Observation leads me also to believe that our entering students are proportionately as well prepared to pursue their engineering studies as corresponding students were forty years ago. At the present time the number of listless students is numerically greater, but I doubt that the proportion of such in the total is greater, or that the preparation and ambition of most of the students are relatively less satisfactory, or that the proportion of adventurous intellectual spirits is less.

Students suitably infected with the spirit of investigation will smilingly carry heavy allotments of mental and physical work and ingratiatingly intimate a willingness for more. About eighteen years ago a large industry offered to the department with which I am related a considerable annual sum of money to be used over a period for improving our advanced instruction and research. We embraced the opportunity to keep the research so much in the consciousness of junior and senior students, as well as graduate students, that it has had a notably stimulating influence. Those of us in that setting think well of the result of this coördination of the teaching and research.

It also may be suggested that the field of the unknown has been exhausted in engineering and that there is nothing left for the enquiring mind, but that comment is only made by those who do not observe for themselves. It is sufficient to answer: Look around and observe, study the development of engineering in the past and present and you will discover a speed and width of the front of growth in all branches of engineering which now rivals if not excels any previous era.

This is a period suffering from a flood of pre-digested textbooks, reliance on conventional laboratory assignments, and presentation of formal lectures. The cry is made that these processes are necessary in order that the students may learn all that they should learn, and that there is no time left over for cultivating an investigatory spirit. My answer is that resourceful foresight and self-reliance (set against pepsinized hindsight and common industry) will always win in the end; and we develop the winner when we develop investigative spirit and resourcefulness,

even if some store of secondary facts is neglected for lack of time. Our situation is illustrated by the old ditty:

> "Could man but be sure that life would endure
> As of old, for a thousand long years,
> What things he could know, what deeds he could do,
> All without hurry or care."

Recognizing that life is short we must reconcile ourselves in education to selecting the most serviceable of various possible processes, remembering that the sweep of time does not permit us to embrace more. In making our choice of processes, however, we must try to make sure that the choice is of the most serviceable.

Albert W. Smith, known to most of you as former Director of Sibley College and before retirement as Acting President of Cornell University, but to some of us known earlier as a remarkable teacher of machine design, held that no teacher should teach from a textbook written by another. This is a way of saying that the work of the engineering teacher should constantly grow under his hand; and also is a way of stating that the enquiring, forward-looking mind and the spirit of investigation are essentials to foremost engineering teaching. Unhappily, textbooks written in that spirit often are received coldly as "to hard", and a preference is exhibited for the predigested, backward-survey types.

Can any one doubt that the influence on their students and in engineering education of, for example, Irving Church, Mansfield Merriman and George Swain was in large part due to their resourceful originality and investigative spirit, standing foremost day by day as an example before their students? Engineers must deal with physics, economics and psychology, materials and forces, the philosophy of wealth (in the technical sense), and Man. It is not a mental accumulation of facts alone that fits young men for doing this, but an understanding of interrelations of facts and the methods of detecting and identifying facts is of the essence. Our theories of action, relating to man or to mechanical design, are formulated from relatively few fundamental facts associated with a multitude of keenly recognized permutations of their relationships.

Detecting and identifying facts and discovering their varied relationships is research. Properly directed research is a potent instrument to arouse the ambitions and exercise the reasoning powers of students. It also teaches them to use foresight in planning and a responsibility for carrying through. It exposes them to early observation of the many faceted purposefulness and everlasting persistence of nature. It may result in important discoveries, which is another function. Universities and colleges (in-

cluding engineering schools) have several functions to perform. One of these is the search for truth, and in science we interpret this as seeking for new facts, disclosing previously unobserved interrelations, and more fully illuminating facts and relationships previously announced but still partly obscure. In engineering we weave this function into a fabric along with economics and psychology and have a still more complex compass of research than characterizes any exclusive science. The field is magnificent and must be cultivated. Research is an inspiring part of the life of colleges. The spirit for establishing research laboratories and foundations in engineering schools is a presage of good educational spirit in the schools. The proper interpretation of the situation is important.

We must remember that universities and colleges have education for their prime function; and it being my thesis that research is part of engineering education, students of suitable advancement should be invited into the research precincts to there take up tasks. To set up research laboratories and libraries and bar out students of suitable advancement from pursuing work therein would be inappropriate to university ideals and to the weaving of the best fabric of engineering education. Research laboratories dedicated to and carrying on fundamental research of high order gloriously serve the advancement of mankind through their investigations and discoveries. When so directed that the atmosphere of independent achievement is allowed to spread into the haunts of upper-class students, as well as to graduate students and teaching staff, they collaterally make large contributions to educational results and thus their value to civilization is multiplied.

GRADES AND MINIMUM ESSENTIALS *

By R. B. WILEY

Professor of Sanitary Engineering, Purdue University

Many instructors have a feeling that grading is of only minor importance and is therefore hardly worthy of careful thought or serious discussion. Some, going even further, claim that our method of breaking a line of study up into units with a grade for each unit serves to defeat the main purpose of education. They claim that knowledge cannot be thus segregated and that in such an attempt the student loses entirely his sense of perspective and becomes more interested in working for a grade than in achieving proficiency in his chosen field. Yet no matter what our beliefs may be as to the proper educational system we all admit that if standards are to be maintained for the degree there must be a day of accounting when the achievement of the student is determined. Whether the units shall be large or small may be debatable, but that the student at some time must be measured by some intellectual yard stick and that the results of this measurement must be entered on his record is admitted by all. The results of such measurements, *i.e.*, grades, are, therefore, a necessary part of our educational system. The instructor who fails to be discriminating in his grading is also failing in his duty toward his students because to them grades are of major importance since they represent the permanent record of achievement on the books of the university.

A factor which is often overlooked is the effect of the grading standards of an instructor or a department on the balance of the curriculum. The faculty has apportioned the work that can be demanded of a student by assigning credit hours to the various courses on the assumption that the student will spend approximately the same amount of time in preparation for each class or credit hour. It is assumed that variation in profundity of subject matter is compensated by variation in time devoted to the subject. Any instructor by the mere variation in his standards of grading can easily demand and secure a variation in the amount of the student's time. The instructor who grades rigidly and gives a high percent-

* Presented at the 39th annual meeting, S. P. E. E., Purdue University, June 17–19, 1931.

age of failing grades may easily secure a larger portion of the student's time per class hour than the one who is lenient, other things being equal. This will inevitably throw the curriculum out of balance.

There are those who maintain that the symbols used for the different grades should never stand for a word that is in any way descriptive of the grade. This is merely another way of saying that the instructor, when making out his grades, should not concern himself with the use to which grades are to be put. In this they assume that there is some rigid arbitrary method of arriving at a grade which is independent of the instructor's judgment. Most of us acknowledge this reasoning to be fallacious and admit that, in a last analysis no matter what the basis, the judgment of the instructor is the most important element. Whenever a person is required to exercise judgment he should have constantly before him all the facts which might influence his decision. One of the most important facts is the use to which the grade is to be put.

To adhere strictly to the normal-curve distribution and say that 5 per cent or 10 per cent of the students of a given class must fail because that is the normal expectancy is obviously just as absurd as to say that there is no such thing as a normal expectancy of failure under our present system.

A failing grade immediately limits the progress of the student and this fact is all important in assigning such a grade. The instructor should first decide whether or not the student's achievement is such as to warrant his continuance toward graduation, his continuance in dependent lines of work, his continuance in the university.

Much of the confusion which has arisen in connection with grading systems has been due to a lack of definite understanding of the purpose of a grade. The primary use of a grade would seem to be to place a reliable record on the books of the university showing the attainment of the student in a given course. This permanent record then is used to furnish a basis not only for dropping, promoting or graduating students but also for awards, honors and scholarship prizes. Furthermore it informs the student, his parents and the world of the nature of his attainment in a course and frequently serves as a stimulus to greater intellectual achievement. The most important, therefore, are the failing and honor grades and these should be assigned with the utmost care.

There are two fundamental aspects of educational measurement which grades must fulfill: reliability and validity on the one hand and comparability on the other.

The grade should be a reliable index of the student's "*knowledge*

of and ability to think in the material of the course" (Wood of Columbia) and the grades in different courses should be comparable. All who consider the matter carefully will admit the necessity for a single standard.

Studies of grade distribution have been made at many institutions. At Purdue University a statistical study of grades has been carried on for many years and this analysis indicated very definitely a lack of common standard. Over a period of seven years certain instructors gave as high as 51 per cent A grades (1014 students) and others as low as 5 per cent (1110), some gave as high as 35 per cent failing grades (1110) and others as low as 4 per cent (1746). Over a four-year period one group of instructors giving 29 per cent of the grades gave 51 per cent of the A grades, while another group giving 22 per cent of the grades gave 60 per cent of the failing grades. Not only was there a wide variation in the distribution of the total grades in different departments but there was a wide variation in the distribution of the grades of different instructors in the same department teaching students of the same class and also between the same groups of students in different departments.

All this led inevitably to the one conclusion that there was a lack of a common standard of grading. Different instructors were using the same passing grade to designate different things, thus destroying both the reliability and comparability of all grades. At the time these analyses were made Purdue University was operating under the percentage system in which a faculty rule required that an A grade be given for an average between 90 and 100 per cent, a B grade for an average between 80 and 90 per cent, etc. As a result of these studies Purdue University abandoned the percentage system and, in 1927, put into effect an entirely new system of grading.

Primarily grades depend upon two things: first, methods of testing and marking; and second, the method of resolving the results of tests and marks into a grade.

A great deal of study has been given to testing and marking; and while it is undoubtedly true that much of it is unreliable it is not my intention to discuss this phase of the grading question except to point out that if a grade is to be based on achievement, then the marks which determine the grade cannot be dependent upon chance or upon such things as effort, general intelligence, character or personality, fitness of the student to live in civilized society, amount of improvement of the student in general or in the specific course, absence from class, tardiness or discipline. To give a student a zero for absence and to use that zero in determining

the final grade merely defeats the purpose of the grade. To give a student a failing grade for dishonest practices not only displays a lack of originality in inflicting punishment but falsifies the record.

When all the marks in a given course have been obtained there are two ways in which to arrive at a final grade, averaging and job analysis. We can, by properly weighting each grade, arrive at a mean or weighted average, which represents the student's performance in the course on a numerical scale. Then we can set up an arbitrary scale for obtaining the final grade or we can list the students in the course in the order of their numerical standing and determine the grades by an arbitrarily established normal distribution or probability curve.

It matters not whether we use percentage or some other numerical system in this method, the results will be the same. Therefore, in this discussion only the percentage system will be considered.

If the marks have been objectively obtained, eliminating all possible effects of chance, the average percentage for the term may represent the student's performance; but even that is questionable. The grade, however, should represent not performance but achievement. Under the percentage system the grades become stereotyped and become symbols of performance of one sort or another and not symbols for achievement or ability to think.

H. C. Morrison of Chicago has analyzed the faults of the percentage system so well that portions of his analysis will bear repetition.

"A percentile expression has real meaning only when it is applied to an actual quantity.

"Thus, we speak the truth when we say that a pupil has mastered the correct spelling of 80 per cent of a given list of words. But the expression does not say what it means when it is intended to mean that the pupil is 80 per cent of a good speller. To express a real meaning in the instance last named, it would have to mean that he spells correctly on the average 80 per cent of the words he uses and that would be very poor spelling indeed. . . .

Similarly, we can say with entire truth that a given pupil has mastered one-half, or 50 per cent, of the units in a course in Science and another 75 per cent, but this only means that one has half completed the course and the other has three-quarters completed. Neither grade has any pedagogical significance as part of the record.

"But this exact, mathematical use of the percentile term is not what the school has in mind. It rather uses percentile grades to express symbolically the teacher's judgment of the pupil's perform-

ance. If all kept in mind the principle that the grades thus used were mere symbols without any mathematical meaning, the practice would be acceptable rating of performance. But the teacher does not keep this principle in mind. He rather grades 70 per cent today and 80 per cent tomorrow and expresses the average performance of the two days as 75 per cent. 75 per cent expresses the average of two judgments but it does not express even the teacher's judgment of the value of the total performance of the two days. Even so, learning is confounded with lesson performance and the whole unreal situation leads to ridiculous consequences. If multiplication is the lesson for today and the pupil scores 100 per cent, and division is the lesson for tomorrow and a score of 50 per cent is attained, then 75 per cent is taken to express the learning of the two days. Somehow perfect performance on multiplication averaged with a very poor performance on division must have resulted in poor but acceptable learning in both. In brief, use of the percentile grading as a means of evaluating pupil progress inevitably leads into a world of unreality and no wonder the schools are condemned for slipshod work."

The method of obtaining a student's percentage grade, even if based on a carefully worked out standard, is inaccurate because it is based on measurements of the student's performance at specific times during the course and even though performance is a measure of attainment the mean or average of a series of such percentages cannot possibly be a measure of ultimate achievement. If in the early part of the semester a student receives a grade of 40 per cent on a certain important exercise, that 40 per cent is combined with the other grades to obtain the semester grade even though the student may later obtain a well nigh perfect mastery of the subject matter upon which the original exercise was based. The final grade, therefore, can not represent attainment.

After we have obtained this mean or average percentage grade it must be translated into a symbol for record. It is generally recognized that we can classify students in not more than five groups, and the common method is to use four passing groups with grades from A to D and a failing group which may be further subdivided into those conditioned and those required to repeat the course.

In order to maintain a certain standard for each grade, many universities specify the percentage range for each grade, as was formerly done at Purdue. This quite frequently puts the instructor in the anomalous position of breaking a university rule or giving a student a grade which he knows is not representative of his achievement. If 70 per cent is the passing grade, a student

must, under such a rule, be given a passing grade if his average is 70.1 per cent and a failing grade if his average is 69.9 per cent which is obviously an absurd situation, yet the accuracy with which the mathematical average of a series of percentages can be obtained leads many an instructor to trust such results absolutely.

The unreliability of any such system of grading can easily be shown by an analysis of the distribution of grades where the system is in force.

It is pretty generally accepted that the distribution of grades for large groups should follow the probability curve which may or may not be slightly skewed according to the degree of selection involved. On the ground that failure can be entirely prevented by proper selection and proper teaching, some argue, for example, that there can be no normal percentage of failures. It is likened to typhoid fever, an entirely preventable disease, which should have no normal death rate. It is admitted that there is much room for improvement in our entrance requirements but it is by no means certain that any system can or should be devised which would eliminate all of the unfit lest in the process we also eliminate many who might later develop into very acceptable college-grade material. Even if we accept the thesis that under the ideal selective process and with perfect teaching we should have no failures whatever, we cannot deny that the theory of probability will still apply, although the distribution curve may be skewed by the selective process. In practically all cases in which a rigid percentage scale is in use the grade analyses which have come to my attention show very erratic distributions.

On the other hand while we admit that for large numbers of students the grade distribution should follow the probability curve, it by no means follows that the curve itself should be used in determining any individual student's grade. Some universities do use this method; and while it is theoretically correct for large groups it may be seriously in error when applied to a small group or to the individual student in a large group when that student's position in the group is obtained by averaging a series of percentages.

Because of the inaccuracies of these various systems of grading, Purdue University in 1927 abandoned its former percentage method, adopted a new series of definitions of grades and increased the number of passing grades from three to four, H, A, B and P. At the same time an additional qualitative standard was set up for graduation in the requirement that a student must pass at least 90 semester hours of work with a grade higher than the lowest passing one, *i.e.*, B or better.

The new plan was based on what might be called a job analysis method. Each instructor was required to set up definite minimum essentials in each course; and a student who mastered these minimum essentials but no more was to be given the lowest passing grade, P. If he failed to master these minimum essentials, he failed to pass the course. If the failure was such that in the judgment of the instructor the student could acquire mastery by a reasonable amount of independent work or study he was to be given a condition grade, C, and the instructor was required to indicate on the semester report what additional work the student must do to raise his grade. If the student was seriously deficient in his mastery of these minimum essentials he was to be required to repeat the course and was given a D grade.

In adopting the job analysis method and setting up a definite set of minimum essentials for a passing grade we were not only attempting to avoid the inaccurate percentage method of grading but we were applying to the passing grade a rational principle that applies throughout life. In order to be passably acceptable everything must meet certain definite minimum requirements. In construction we set certain minimum stresses which all materials must meet, in college work there are certain minimum requirements which the teacher must meet. No matter how high his average may be the teacher cannot continue if he fails to meet these minimum requirements which, although not standardized, are yet very real. You all must know of cases of promising teachers who have failed because of the failure to meet some minimum requirement.

The two higher marks, H and A, were defined as honor grades, the highest, H, being reserved for those students of outstanding ability whose work was of such exceptional character as to merit special recognition. They must display imagination and initiative. The University of California has well defined this grade by the statement that in giving this grade the instructor "expresses his belief that if the single course were in question the student should be granted highest honors at graduation." The A grade, passed with honor, recognizes proficiency in attainment but does not indicate special imagination and initiative or exceptional proficiency. The instructor in giving this grade automatically puts the student on the honor list as far as his course is concerned because those students having an average of A or better are placed on the distinguished student list.

The B grade is the median; it is defined as "passed with merit, to be given to the student who presents somewhat more than the minimum essentials required by the instructor for credit in the course." In proposing this grading scale it was the intention of

the committee that the B grade should be the median or basic grade to be given as a "reward for work satisfactorily performed, implying nothing more discreditable than a lack of real distinction" as it was later defined by the University of California.

Under this plan, therefore, if the student masters merely the minimum essentials he is given a P grade which permits him to progress and satisfies the requirement of a rigid curriculum. He has passed the course but the credit hours so obtained do not count toward the 90 hours required for graduation. If he masters more than the mere minimum essentials he is given a higher grade which is dependent upon whether or not he is entitled to honors distinction.

At the time the change was proposed the committee had difficulty in arriving at a probable grade distribution under the new system because it not only involved the introduction of a new honor grade, but had to take into account the trend of the previous years, with an almost continuous increase in the percentage of failures. Where the latter would end no one seemed to know. However, we hazarded an estimate of 5 per cent H, 20 per cent A, 50 per cent B, 18 per cent P and 7 per cent failures. Later, with more information at hand, the committee chairman revised the figures as to advisable distribution to 5 per cent H, 18 per cent A, 50 per cent B, 19 per cent P and 8 per cent failures. The actual distribution for the entire university for the years 1927–29 was 3 per cent H, 20 per cent A, 37 per cent B, 28 per cent P and 12 per cent failures. This indicates that the faculty has not completely accepted the committee's new definition of the B grade and still clings in some measure at least to the old percentage definition.

The introduction of minimum essentials admittedly involves many difficulties. For most of us our experience has been entirely with the percentage system of grading and we find it hard to change. The ease with which we can arrive at a final grade by averaging a series of percentages, the work required in checking up and in retesting, as well as the difficulties in setting up the essentials themselves tend to discredit the system in the eyes of many instructors. Yet the additional work involved is well worth while if it will serve to fix more definitely in the student's mind the things to be achieved, to crystallize in the instructor's mind the fundamentals of his course, as well as to establish a more rational basis for a passing grade.

It is undoubtedly a fact that certain students who aim at a passing grade only will concentrate on the minimum essentials and thus neglect the course as a whole but these same students under the percentage system will be aiming at the 70 per cent average

and can tell to the tenth of a per cent what they must make on the last test in order to pass. The former at least requires the student to achieve in certain definite jobs while the latter merely requires him to "bone up" so that he can obtain the required grade on certain tests.

Under any system it is difficult to recognize achievement, and it is especially difficult to evaluate performance on an all or none basis as in any group there will be all degrees of performance; but judgment is the only basis, and when we operate on percentages our process becomes stereotyped and the final result is not a matter of judgment at all. Under the job analysis method the instructor knows whether or not the student has mastered to his satisfaction each of the required essentials, assuming that his method of testing is sound; his facts are marshalled in much better order, and the result connot be in doubt.

With any learning process the time element is a very important factor. A student may know a thing today and not be able to show that he knows it tomorrow and thus the final examination may become unduly important. He may have forgotten it, a combination of circumstances like too much data in a problem may have misled him into a faulty line of reasoning, or, because of external circumstances, like a boil on his neck, he may make some slip. Perfect performance even on minute details or small jobs cannot be expected at all times; yet it is not nearly as difficult for the instructor to determine when the student has shown reasonable mastery in each of a series of jobs as it is for the course as a whole.

In many courses it is extremely difficult to set up a list of minimum essentials. This is particularly true in descriptive courses and in general courses like English, Economics and History. The list should not be a course outline or a series of lesson assignments in a text book but rather a series of jobs to be done or a series of individual units to be mastered. In Hydraulics for example, since much of the theoretical analysis is based on the definition of certain terms, and on certain fundamental laws, these definitions and laws must be mastered; the student should be able to determine the unit pressure, the total pressure and the center of pressure on any submerged plane area of simple geometrical shape. The preparation of such a list, while difficult, is certainly worth while because it gives the student something much more definite to work on, it requires the instructor to analyze his course most carefully to determine his objectives, and it furnishes the department and school heads an opportunity to strike a balance between the various courses within the department and between the various courses in the curriculum but in different departments and thus calls im-

mediate attention to serious overlapping. The establishment of minimum essentials is generally done by a group of instructors who at the same time are able to relate these minimum essentials to the methods of testing to be used. Thus we have the advantage of the combined judgments of many on both phases of the problem, a valuable aid in grading when we consider the fallibility of human judgment.

Purdue has been operating under this system only since the fall of 1927 and naturally no definite conclusions have yet been reached. Many of the faculty have accepted it as better than the old and many find it hard to depart from the old percentage methods. It is extremely difficult to change human nature and an instructor who gives a large percentage of failing grades will continue to do so no matter what the system.

Admitting that individual grades should not be determined by a probability or normal distribution curve, it is probably true that with a large number of grades a distribution approaching the normal curve can reasonably be expected. One test of an instructor's grading then can reasonably be his distribution; and the publication of this distribution each year has a tendency to compel him to examine more closely into his grading methods or to explain any serious deviation from normal. He will then inquire as to whether his minimum essential requirements are set too high or his judgment as to work of distinction is too low, thus more or less automatically correcting his grading methods.

Discussion

A. D. Moore (University of Michigan): In making a study of such papers as have been presented this morning—and I wish to congratulate the speaker for adding one more good paper to the small list of readable and understanding papers in this field—in reading what has come to my attention (I will put it that way), I have been impressed with the lack of attention paid to what might be one or two fundamentals. Whether they are fundamentals or not, I am not quite sure.

I merely wish to raise one point and state that I have been totally unable to understand its basis in fact, and that is the famous seventy per cent point in the percentage system. I have gone about embarrassing my colleagues at various times with various questions, such as this, as an interesting thing to do. I find if I ask almost anyone in the college faculties, be he an engineering teacher, a teacher of education, or anyone else, why seventy per cent is a passing grade, you may find he knows that it is or you may find he doesn't know it is. Usually he will admit it (or something near it)

is a usual passing grade. You ask him why, and almost invariably he does not know. It is part of his habit of thought, and that is the best reason he has for it.

Why on earth the high schools, for example, should compress the majority of students and the measurement of their achievements into a three-tenths range of the 100 per cent scale, thus failing to differentiate between their very broad range of performance, and then give the remaining students seven-tenths of that per cent scale, I have always been unable to understand and can't yet.

I wish to confess here that in giving examinations to juniors and seniors over a period of fourteen years, I have found I am utterly unable to write examinations that will bring in an average performance of higher than sixty per cent. The average is usually around fifty per cent, and often forty.

I may say here I have not the least feeling of guilt in the matter. I am beginning to suspect I might be able to write a final examination based on memory of facts alone and make the results look something like a 70 to 100 per cent passing grade for the majority of the class. But the moment I try to introduce any problem work into the examination, down will go the grades. Personally, I don't care. That, however, is not the main point I wish to raise.

Here (in the paper presented) are certain distributions. We need, like everything, to study such distributions and find out about what we are doing. Largely, we don't know.

The probability curve has been mentioned. I am very glad to hear a warning given not to use it in specific instances too religiously, and all of that but it seems to me there is one fundamental concept that must be adopted or we are bound to keep on doing muddled thinking and remain in a chaotic state.

I do not know whether or not you will like the concept I am going to propose. Furthermore, it may be an old concept and I simply happened to stumble on it. If I am out of date I will be glad to confess it here. But, for one thing, we think of our grade distributions in terms usually of undergraduates. But the product of a college is its graduates.

I think the first thing we want to do is to find out what our survivors (graduates) have done, and try to put everything we can in terms of that.

If I may set up a purely hypothetical ideal and, for the time being, invent him and present him to your attention, let's take what we might call a B graduate. Let it be the B on this scale here, if you please, and assume that this ideal, unchanging, constant student has been so constant that he made a B grade in every course he took throughout college. That would be quite a phe-

nomenon, but let's agree there could be such a thing for theoretical purposes. If that were true, it would look, for instance, as if each course had been so weighted in its difficulty, and the measurement methods had been so well conceived that this man with a B intelligence, B interest, and so on, had been properly measured throughout.

I would make the proposition that in arranging the difficulty of our work, in distributing our grades, and so on, the hypothetical student (let's say a B man) ought, when we study his record throughout college, on the whole to have made a B grade throughout most of his courses, and usually should have departed only one letter grade up or down from that in the courses here and there.

There are all kinds of objections to this hypothetical man I have been speaking about; so to bring it into practical significance, suppose we pick out 1,000 of our graduates at random and find out what their grade distribution has been as a whole. The proposition is, if I can make it clear, that the grade distribution for these 1,000 graduates as a whole ought to dominate the scene, and that the total grade distribution for the four years ought to look like that of any one year out of the four. This is simply based on the well recognized idea that when a man comes to college he brings a certain amount of intelligence with him, and we don't increase it. We improve his use of intelligence. I am trying to insist that difficulty of courses, methods of measurement and distribution of grades ought to be such that with allowances for variations in health, interest, and this, that, or the other thing, the usual man ought usually to stick pretty closely to his letter grades throughout his career. If we will not agree to that principle, then there is only one other choice to make; and that is to find out and set up and prepare some kind of rise or fall of usual performance for an average man.

J. E. Boyd (Ohio State University): The previous speaker raised the question as to whether the grades received by a given student from different instructors run fairly uniform. They do. For a study of records of students of mechanics which Professor Poorman prepared one year ago, we looked up the grades of five successive classes of our students in two years of mathematics, one year of physics, and one year of mechanics. Our recorded grades are A, B, C, D, and E. Of which E is failure and D is low pass. A student whose average is B is found to have a large number of B grades, with some A and C grades. Rarely does he have a grade as low as D. A still better man has A and B grades, with seldom a C. A man with several E grades has most of his others D. Grades of a student run true to form in allied

subjects with a large number and variety of instructors. The giving and grading of examinations is not the hit and miss affair which many writers (some of them university presidents) would have us believe.

The previous speaker stated that he was unable to get from his colleagues a statement as to the meaning of the passing grade of seventy. I think most of you who teach have a clear idea of what is meant by a given grade. Our passing grade is sixty. To me this means that an examination which I prepare must contain questions and problems on which the student can make a grade of sixty per cent, if he has mastered the minimum of mechanics necessary to enable him to go on with subjects for which the course is a prerequisite. The remainder of the examination may be of increasing order of difficulty. The student who can make from ninety to one hundred and get a grade of A is regarded as having done as well as reasonably could be expected.

We hear a lot of talk about getting along without examinations and records, mostly from men who do not teach. If I had a limited number of the same students for a year or two in class-room and laboratory, I could evaluate their achievements without examinations or records. Still, I am sure that I could give a fairer rating if I had required a number of progress examinations and based my estimates on records rather than on memory. A teacher should not waste his time bookkeeping, but a little bookkeeping is not wasted.

The standing of the student should not depend alone upon a single final examination, whether given at the end of a term or as a comprehensive examination at the end of two or more years, unless ample time is allotted to really cover the subject and not merely hit the high spots. In the department of mechanics forty per cent has been the maximum for the final at the end of a term or semester.

I think that we grade our students fairly well. The fact that different instructors in allied subjects agree so closely, gives me confidence in our present methods. I may be an old fogy, but, as far as mechanics is concerned, the old percentage method is as good as any. For the university records letters are convenient. However, it makes no real difference what system is used, provided the man who makes out the examination questions fits the questions to the system. If he does not, no system of grading can save the student from injustice.

W. T. Magruder (Ohio State University): I would like to ask Professor Wiley what his objection is to giving a failure to a man who has been caught in dishonesty on examination.

R. B. Wiley (Purdue University): It all depends on what you consider to be the function of a grade. To my notion, a grade in the registrar's office is a record of a student's achievement. If he cheats that doesn't mean he hasn't achieved or doesn't know. It has no bearing on his ability to cheat. If he cheats, put it down on the record that he cheated.

Professor Magruder: Would you give him an A or an H?

Professor Wiley: If he earned it.

Professor Magruder: By dishonest methods?

Professor Wiley: I would not give him any grade at all. I can not see how the question of honesty or dishonesty has anything to do with the student's ability to think.

Paul Cloke (University of Maine): How are you going to determine the grade? If a man cheats on an examination how are you going to evaluate it?

Professor Wiley: I would not consult the examination on which the student cheated to determine the grade.

Professor Magruder: What is your present practice?

Professor Wiley: When a student is caught cheating he is referred to the Dishonesty Committee. The Dishonesty Committee hears the case and makes definite recommendations as to what the punishment shall be. If it is cheating on examination he is, of course, dropped from the course and required to repeat. He may be required to take an additional course of the same weight as the one in which he was caught cheating. We have had reports from our committee, in which the student has cheated on some minor exercise, recommending that he be given a zero for the exercise.

My point is that that sort of a record should not go into the computation of the grade itself, but that some other sort of punishment should be devised. I don't say that a student should be allowed to cheat and "get away with it" and that the grade should then be based on the results of that cheating. Certainly not, but just exactly what happened ought to go down on the record and should not be concealed in the semester grade.

M. F. Sayre (Union College): As I understand Mr. Wiley's explanation, an important feature of his plan is a provision for a more or less definite percentage of failing grades, this percentage remaining the same for all courses throughout the college curriculum. I fail to understand the reason for this uniform percentage.

We start out with students who in most cases have undergone only a very mild process of selection. During the freshman year, then, grades should be more or less evenly distributed, according to an unskewed probability curve. By the end of the freshman year, these same men have undergone a rather rigorous process of

selection, and one should have thereafter a skewed probability curve. On that basis, the percentage of failing grades should not be expected to remain the same throughout the four years.

One more point. Certain subjects in the freshman year are much more vital to the future progress of the student than are others; or, to put it in a different way, certain subjects serve as much better criteria of the likelihood of the future success of the student, than do others. The mechanical method of grading here outlined seems to me to fail to take this fact sufficiently into account.

SYMBOLS STANDARDIZATION

By SANFORD A. MOSS

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"aaaaaaa ccccc d eeeee g h iiiiiii llll mm nnnnnnnnn oooo pp q rr s ttttt uuuuu." This is the way in which Huygens announced a discovery in 1655. The general idea at this era was to surround a scientific statement with as much mystery as possible in order to increase the mental effort required to master it. The reader must admit the success of the plan. Such anagrams then were used quite extensively, and Hooke's law of elasticity, giving the constant ratio between stress and strain, was announced in the same way. Huygens afterward restored the letters of his anagram to their proper places and published "Annulo cingitur, tenui plano, nusquam cohaerente, ad eclipticam inclinato." This statement was in Latin, so that it was still clouded in mystery for the average reader. The translation is "The planet is surrounded by a slender flat ring, everywhere distinct from its surface, and inclined to the ecliptic" and gives the first mention of the rings surrounding the planet Saturn. Even in recent times, it was considered desirable to surround a statement of a scientific or mathematical fact with some difficulty so that a certain amount of mental effort had to be spent before a reader was put in possession of the fact, and before he could concentrate on the mastery of this fact. There even still exist a few college professors who for the sake of the mental drill which is supposed to accrue by using an unabbreviated method, do not permit their students to use short cuts in solving a formula. Fortunately, such ideas are practically abandoned in modern times, from realization that it is desirable to put a reader in possession of a fact or formula with the least possible expenditure of mental effort on the language or form of the formula, in order to permit concentration on the fact which the formula conveys. The most important thing which can be done to secure this is to arrange that all authors writing on a given subject shall use the same mathematical symbols in their formulas. For example, D in a formula always denotes "Diameter." Readers readily learn such a set of standard symbols and are thereafter saved an appreciable amount of mental effort. The mind can then be concentrated on the subject matter itself rather than on the language in which the subject matter is expressed. At the present time a university stu-

dent who may be taking courses in engineering thermodynamics, physical chemistry, theoretical chemistry, and chemical engineering, usually finds an entirely different set of symbols used for given concepts, in each of the departments mentioned. The mental readjustment that is required each time a student starts a new recitation gives a handicap which easily could be eliminated.

Symbols Standardization.—In order thus to make texts carrying formulas as easy as possible, a project was initiated some years ago—"Standardization of Scientific and Engineering Symbols and Abbreviations"—under the sponsorship of the American Association for the Advancement of Science, the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the Society for the Promotion of Engineering Education, to be carried out under the rules of the American Standards Association. As a result, there now exist lists of mathematical symbols for use in formulas in Hydraulics, Mechanics, Structural Engineering and Testing Materials, Heat and Thermodynamics, Aeronautics, Photometry and Illumination, Electrical Quantities, and Mathematics, which are American Standards or American Tentative Standards. These lists can be obtained from the American Standards Association, 29 West 39th St., New York City. Each of these lists was prepared by a competent committee in its individual field. The symbols were selected in each field so as to take account of current practice, and in the frequent cases where there was diversity of practice, to adopt the symbol most likely to meet universal acceptance. Many cases, of course, were found where a given concept occurred in several of the lists. It has been possible to use the same symbol in nearly every instance, and it is seldom that a given concept has a different symbol in different lists. In view of current practice in the respective fields, such few cases were accepted as inevitable. All of the standardization mentioned is for Symbols used in mathematical formulas. The same project also includes standardization of Graphical Symbols, as used on drawings and plans, and of Abbreviations, as used in a body of text or in tables and headings. A few of the lists in these subjects are complete and a number nearly complete.

Acceptance of Standard Symbols.—Standardization in general is a very modern development. Only a few years ago, every manufacturer of machinery made his parts to suit himself and used his own system of bolt threads, etc. Such an arrangement was considered very desirable because then new bolts and other parts for repairs would have to be purchased from the original manufacturer. On this basis, every author would use his own set of symbols in an effort to compel readers to use his own publications ex-

clusively. There is no need to go into the advantages arising from the abandonment of such ideas and the standardization of bolt threads, pipe threads, carburetor flanges, taper fits, and thousands of other machine items. Similar advantages will result from symbol standardization.

There have always been a great many conservative people who question the wisdom of machine standardization. Exactly the same thing will, no doubt, occur with respect to the standardization of symbols. Many authors will ignore the advantage to their readers of the use of the same symbols which everyone else employs. Other writers will want to wait to see if everyone falls in line before abandoning their own symbol customs and adopting the standard ones. In many cases, the real reason back of such an idea is the mental inertia of the author himself to change his own habits. Often an author writes in terms of heterogeneous lot of symbols to which he has become accustomed, beginning with his own experience as a college freshman. It is of course natural that an author should feel that the symbols which he uses are in general use, whereas actual investigations would show equal or greater use of other symbols. Of course, the easiest and laziest procedure is that an author will continue use of his own symbols without question. The more effort, however, that an author spends in making his symbols as well as his text easily managed, the more popular he will be with his readers.

Principles of Symbology.—Modern customs with respect to symbols, signs, and forms of mathematical expression are the result of evolution since the first mathematical writings of the ancient Chaldeans, Egyptians, and Hindus, and continuous changes have occurred, all directed toward simplicity in expression. The original Egyptian and Hindu algebra had a form which was very hard to understand, and multiplication and division with Roman numerals was a very serious operation. However, all such items have been perfected by centuries of work, so that present customs with respect to symbols, signs, and forms are the best means known, at the present time, to minimize mental effort.

It is often thought that use of words or abbreviations instead of letter symbols will make mathematical expressions more easily understood by people who are not used to them. For instance, the following are two ways of stating the same fact.

a. The circumference of any circle is found by multiplying the number representing the diameter of that circle by the number 3.1416.

b. $C =$ circumference of a circle,
$D =$ diameter,
$\pi = 3.1416$,
then $C = \pi D$.

It is probably true that if an individual were to have use for such a piece of information at rare intervals, the form (*a*) would be preferable. If an individual, however, is going to use such information frequently, it will be much better for him once and for all to make the slight effort required to learn that (*b*) gives the same information as (*a*), in order that his mental effort thereafter will be minimized. Many people give themselves extra mental work for years by continuing to need expressions such as (*a*). If they would devote perhaps half an hour to learn the use of expressions such as (*b*), they would thereafter be much better off. Possibly instruction in elementary algebra is deficient in this particular item. A person who continually uses expressions such as (*a*) instead of expressions such as (*b*) is in about the same state as a person who has to walk everywhere he wants to, because he has never made the slight effort to learn to climb into a street car or an automobile.

The term "symbol" or "mathematical symbol" applies to a sign or letter used in a mathematical formula or equation, as a representative of some number which is to have performed on it the operation indicated by the equation. A "mathematical sign" is an indication of a mathematical operation which is to be performed. An "abbreviation" is a shortened form of an expression or word, to be used in texts, tables, or headings, but never to be used in formulas. A "chemical symbol" is a representation of a chemical element, used in chemical formulas. These are already standardized internationally, and need not be discussed here. A "graphical symbol" is a sign used on plans or drawings to represent a certain object which is to be erected.

The following are examples of the use of *C* in all of these ways. The meaning in each of the ways is so obvious that there is no chance of confusion with the other ways.

$$C = \pi D.$$

This is a mathematical formula and *C* is the symbol for circumference.

$$V = (2gh)^{1/2}.$$

This is another formula, and (is a mathematical sign which with another sign) denotes that 2, *g* and *h* are to be included together.

Temperature —20 C.

Here C is used as an abbreviation for Centigrade.

$$C + O_2 = CO_2$$

This is a chemical formula and C is the chemical symbol for the element Carbon.

This is part of a wiring layout and denotes that a circuit breaker is to be inserted in an electric line wire.

The reason for the rule that abbreviations are never to be used in formulas is the extra labor and opportunity for confusion which would be involved by using expressions such as the following third way of stating the fact given above.

(*c*) Cir. $= \pi \times$ Diam.

It is now the universal custom in algebra that when letters in a formula follow each other without separation they are to be multiplied together. That is, "*abc*" means the product of "*a*," "*b*" and "*c*." According to this rule, "Cir." would mean the product of "C," "i" and "r." If formulas sometimes had groups like "Cir" which represented a single expression, and at other times groups like "*abc*" which represented three individual numerical values, confusion would of course occur. It has therefore become a rule that a symbol used in a formula should always be a single letter, and never a combination of several letters or an abbreviation.

When there are a number of quantities of a single kind which are to be distinguished from each other, subscripts are used which are minor letters succeeding and placed slightly below a major letter and forming with it a single symbol. Therefore, the way to handle quantities such as inside diameter, outside diameter and pitch diameter, is by use of symbols such as, D_i, D_o, and D_p. It has often been proposed that such quantities should have the symbols, *ID, OD, PD*. Once again, if a person who is to use symbols will take the very slight amount of time required to understand the very general use of D_i, D_o and D_p he will thereafter be saved mental effort.

In a recent attempt to use a group of letters as a single symbol, with an idea of making a formula easy to understand, there occurred the following formula

$$VS = VPig + VPip.$$

With use of symbols according to the standard system, this formula would have been.

$$V_s = V_g + V_p.$$

It is certainly easier in the long run to use formulas based on this standard system.

It is to be noted that sin, cos, tan, etc., used in formulas for sine, cosine, tangent, etc., are mathematical signs. For example, consider the expression,

$$a/b = \cos \theta.$$

Here "cos" is a sign denoting that θ is to be submitted to a certain mathematical operation called "taking the cosine," and the resultant value called "cos θ" is a symbol to be used in the formula. It should always be obvious that "cos" is a single mathematical sign and not a group of symbols c, o and s, whose product is to be taken. Modern practice in the use of the signs for trigonometric functions never gives rise to any question in such a case.

A very common disability with respect to symbols, unfortunately most prevalent among the better authors, is the definition in the midst of the text of each symbol at the first place it is used. Then the deduction of most equations is preceded by several symbol definitions, "Let V be the peripheral velocity. . . ." For instance, a leading book on the theory of gases gives, in the midst of a paragraph, ν (Greek letter nu) as the symbol for "molecular density." Thereafter in the formulas ν is used without further definition. Three or four chapters on, if the reader has forgotten how ν was defined, he must go back and search through the text to find the place where it is given. This particular book commits another serious offence, by also using λ, μ and ν as direction cosines, to define the direction of a vector, so that the same symbol ν is used with a second wholly different meaning. After a few equations using ν with the second meaning, comes an equation using it with the original meaning. The author is so engrossed in his subject, and is so familiar with his own symbols that he assumes that his readers are equally expert, which is far from being the case. The mathematics in this particular book are very difficult and possibly the author feels that anyone who can master them does not need to have a symbol system easy to understand. Yet the present writer and no doubt many others often lose hours in trying to puzzle out a mathematical text book because the author has not given a definite statement covering certain symbols. Fortunately it is getting to be a common custom to include in a book or article a complete list of all of the symbols used.

In a text book or even in a mathematical article, it sometimes happens that it is desirable to use a given letter for two or more independent concepts, which of course is shown in the Table of Symbols. If the equations containing the two uses are entirely distinct, no confusion will be caused. For instance, n is the standard symbol for revolutions per unit time as well as for the exponent in the gas equation $pv^n = C$. If there is any possibility for confusion, a subscript must be used for distinction.

Résumé of Rules for Using Symbols for Conservation of Mental Effort

1. An author should realize that before his readers can begin to understand his subject matter they must master his symbols. Therefore, it is worth considerable effort to transmit to the reader a convenient and easily understood set of symbols.

2. A complete table of the symbols used in a book, article or paper should be given, preferably at the beginning, where it will be certain to strike the reader's attention. If the symbols are wholly or largely given in an A. S. A. list, this will, of course, be mentioned. These lists are not yet widely enough circulated to warrant omission of the author's list. Such a table will eliminate the very poor practice of defining an often used symbol in the text the first time it is used, which compels a reader to search through the text time after time to find the meaning of each symbol, when he is going over equations. However, if a symbol is used once only, and never referred to again, it is proper to define it in the text at the one place when it is used, so as not to burden the Table of Symbols. On the other hand, all symbols used more than once should be given in the Table of Symbols, and not alluded to in the text at all.

3. The symbols of that one of the various A. S. A. lists which is nearest to the general subject of a given text should be used. Of course, it will often occur that an author will need symbols not in this list, and then search must be made of related lists. If no list contains a desired symbol, a symbol of a related concept may be used with a subscript. If this is not possible, a new symbol must be selected, naturally following whatever current practice may exist.

4. When in a given discussion, different concepts from one or more lists of A. S. A. or other suitable symbols have the same symbol without alternatives, this symbol preferably should be used for each concept. If there is any possibility of confusion, there should be added subscripts, selected by the author, in all cases or all but one case.

5. Various quantities related to a concept for which a symbol is given in an A. S. A. list, are to be denoted by the given symbol, with subscripts, usually to be selected by the author. Thus, various diameters are to be denoted by D_1, D_2, D_a, D_b, D_4, etc.

6. The same symbol should be used for a given concept, regardless of the number of special values which occur, and subscripts or superscripts should be used to designate special values.

7. Letter subscripts should be used to denote values under special conditions or in special states. A subscript consisting of

two letters (not separated by a comma) denotes a value or a change of value between two conditions or states. For example,

Specific heat at constant pressure	c_p
Specific heat at constant volume	c_v
Thermal efficiency	e_t
Mechanical efficiency	e_m
Heat content of dry saturated vapor	h_g
Change in specific volume during vaporization	v_{fg}

8. Numerical subscripts should be used to denote values at designated points in an apparatus, process, or cycle. A subscript consisting of two numbers (not separated by a comma) denotes a value or a change of value between two points, sometimes requiring specification of path. For example,

Initial pressure	p_1
Final pressure	p_2
Weight of a major item	W
Weights of auxiliary items	W_1, W_2, W_3
Heat per pound transferred between point 3 and point 4	Q_{34}

9. The same symbol should be used, regardless of units. Thus v is specific volume, whether c.c. per gram, c.c per mol, or cu. ft. per lb. be used.

10. In cases where more than one system of units is used in a discussion, a single symbol may be used, with addition of subscripts, superscripts, or indices to denote units other than the primary one. For example, p, p_g, p', P''.

11. In order to increase the clarity of printed matter, which is practically always Roman, symbols alone or in equations should be printed in italics.

12. Where possible, capital letters should denote total quantities and small letters should denote specific quantities, or quantities per unit. For example, S may be entropy of any mass, and s may be entropy of unit mass.

13. A symbol for a single concept is always to be a single character, with or without subscripts. Two or more characters together of equal rank denote a product.

FUNDAMENTAL ERROR IN THEORY OF VISCOSITY

By B. F. GROAT,

Consulting Engineer, Brookline, Mass.

This subject is discussed in a paper on the theory of similarity and models by the writer in *Proceedings Am. Soc. C. E.*, August, 1931, pp. 933, 965, 989.

It is a most remarkable fact that two of the greatest men of all time fell into error when they dealt with comparatively simple, but deceptive, theory in the science of dynamical viscosity.

It was Newton who first laid the foundation for the theory of viscosity * by making the hypothesis that the "internal friction" of fluids is directly proportional to the relative velocity of neighboring parts. In the first application of his hypothesis he made an error † which was pointed out by Stokes ‡ in 1845. The science of dynamical viscosity is so termed by the writer because Newton's hypothesis, when properly applied, solves every problem in pure viscous flow (p. 948).

Maxwell's first paper on the Dynamical Theory of Gases § contains the first treatment of the theory of viscosity as applied to gases. He distinguishes the motion of flow ("mass-motion") from the random molecular velocities (heat motions), and proceeds to calculate the resistance to the flow on one side (upper side, say) of a plane of separation parallel to the direction of flow. He does this by assuming that the resisting impulse is equivalent to the difference between the "transfers" of momentum (relative to mass-motion) in the upward and downward directions across the plane. He associates this resistance with the plane of separation, and calls it the shearing force in the plane. He assumes also that each molecule travelling over a free path carries along with it the mass-motion appropriate to the point of beginning of the free path.

By Newton's second law, change of motion is proportional to force applied, and takes place along the straight line in which the force acts. It follows from this law that Maxwell was not entitled

* Principia (1687), Hypothesis, Lib. II, Sec. 9.

† Principia, Lib. II, Prop. 51.

‡ "On the Theory of the Internal Friction of Fluids in Motion, and of the Equilibrium and Motion of Elastic Solids," Cambridge Transactions, t. VIII, p. 303.

§ *Phil. Mag.*, June and July, 1860; Collected Papers, Vol. I, p. 377.

to consider the transfer of momentum across the plane of separation, but that he should have considered only the actual changes of motion of the molecules which enter the flow by crossing the plane to the upper side; that is, to consider only the molecules moving upward. Correspondingly, to find the impulse upon the gas on the other (lower) side of the plane, he should have considered the changes of motion occurring to only the molecules moving downward.

It is a corollary to Newton's laws of motion (p. 969) that the mere removal of a mass from, or its addition to, a system of particles moving with a common velocity cannot have any impulsive effect upon the system when that mass has the common velocity of the system, or when it does not collide with (or act upon) any molecule of the system.

It is failure to recognize this fundamental truth which has caused Maxwell's numerical coefficient (1/3) in his formula for coefficient of viscosity to be twice as large as it should be. The correct formula based upon Maxwell's theory is $\mu = 1/6\rho\bar{c}l$.

A sufficient analysis is given on pp. 965–989 of the discussion, but it may be permissible here to state some of the consequences of the error, which seems to have been repeated by all analysts since Maxwell.

In the first place, it may be remarked that the error is entirely distinct from those numerous corrections of the numerical coefficient which have been proposed, or adopted, by reason of changes in the method of averaging. All these methods which apply momentum transfer as it has been used in the kinetic theory are subject to the same error,—the calculated coefficient is double what it should be. This probably requires considerable revision of textbooks, and tables of constants, since the best values of free path, molecular radii, and other molecular magnitudes, are obtained from experimental values of the coefficient of viscosity.

The foregoing facts result from investigation of questions raised in the discussion of the main paper. Detailed calculations are verified in the closing discussion by methods not involving explicit use of momentum. It is noticed that the only way in which two or more bodies can be brought to a common velocity by their mutual actions is that these actions have the precise effect of being perfectly non-conservative (inelastic). Hence, it is explained in the discussion how it can be, that the supposedly perfectly elastic mutual actions of molecules of the kinetic theory can become wholly non-conservative (inelastic) when changes of mass-motion are involved. The convertibility of mass-motion into molecular motion is the necessary mechanism which supplies to elastic molecules the property of effective inelasticity. There is evidence to show that

the kinetic theory will agree better with experiment after the errors are corrected as indicated.

Since writing the foregoing paragraphs Professor E. H. Kennard, of Cornell University, has contributed discussion, the nature of which is summarized in the following two letters:

TEXT OF LETTER FROM E. H. KENNARD.

ROCKEFELLER HALL, Sept. 4, 1931.

From your letter of August 25th it appears that my letter must have been very obscure. I will not trespass further with any lengthy discussion, but perhaps I may be permitted to offer the following summary of the situation as I see it.

You have pointed out no error. Your formula $\mu = 1/6\rho\bar{c}L$ agrees with the one usually obtained in kinetic theory. The L in this formula stands for the mean free path of all molecules crossing a given plane or level, which is twice the ordinary mean free path; if we substitute for your L the quantity $2L$ where L *now* stands for the ordinary mean free path, your formula agrees exactly with the one given for instance in equation 765 in Jeans.

REPLY TO LETTER FROM PROFESSOR E. H. KENNARD (SEPT. 4, 1931) RELATIVE TO KINETIC THEORY OF VISCOSITY OF GASES

Your letter of 4th inst., and previous letter which I understood perfectly, were welcome—in fact, I want to co-operate in any serious effort to improve kinetic theory. One of the great difficulties in achieving this is to secure the analytical attention of those who are most familiar with kinetic theory, as anticipated in the second paragraph of Art. 20, p. 969, of my paper on Theory of Similarity and Models, *Proceedings*, American Society of Civil Engineers, August, 1931. I shall refer to this paper again.

You have summarized the situation as you see it. Here is my summary:

(1) In my paper (pp. 968–989) is demonstrated the theorem that momentum transfer, as it has been used in the kinetic theory of viscosity of gases, is invalid. Since you do not mention or disprove this, you must accept it as a mathematically and dynamically exact theorem.

(2) Jeans demonstrates his equation (765), to which you refer, by use of momentum transfer. Therefore, this equation is invalid, and it is not proved that the coefficient of viscosity is equal to $1/3\rho\bar{c}L_m$.

(3) I shall pass no further criticism unless it should be desired later.

(4) When the transverse velocity gradient is straight, a simple modification of Loeb's treatment (Kinetic Theory of Gases, Art. 59, p. 183), made by rejecting momentum transfer and substituting correct dynamics in its place (see my Art. 23, pp. 973–981), easily produces a correct general formula, $\mu = 1/6\rho\bar{c}L$, where L is the mean of all the free paths which cross a plane of shear, and μ is the coefficient of viscosity. This is the mean free path of my paper. In terms of the general mean free path,

L_m, the formula becomes $\mu = k\rho\bar{c}L_m$, in which the coefficient k depends on an averaging function, $\psi(r)$, where r is any particular length of free path. Hence, k depends upon the form of the function and the limits of the integrations. I append this solution below for your information, and suggest you give it your careful examination with reference to my paper. There isn't a chance in millions that $k = 1/3$. The probability of a free path being terminated by a collision is less immediately after a collision than it is later, on account of shielding action by a near-by molecule. The maximum length of free path should never be infinity. It should be limited to a finite, but not necessarily definite, magnitude. With many types of functions you will find that the ratio of mean free paths, of the two kinds considered, is independent of such indefinite limits.

(5) Your insertion of $2L_m$ for L in my formula (see above) means nothing, since it is always possible to secure from a formula any desired result by making a compensating assumption.

(6) The mean length of straws falling across a crack, is not necessarily twice the average length of all the straws, but depends upon the distribution of lengths among all the straws.

(7) All the general conclusions of my paper are re-affirmed, including those relating to the kinetic theory of viscosity, namely, that both kinetic theory and corresponding physical constants contain errors which should be corrected in treatises and tables.

(8) The formula for coefficient of viscosity is (appended as mentioned)

$$\frac{\bar{c}}{4\pi L_m}\int_r^{r_m}\int_0^{r_m} x\psi(x)dx\,dr\int_0^{\pi/2}\cos^2\theta\sin\theta d\theta\int_0^{2\pi}d\varphi,$$

in which r_m is the maximum possible length of free path, as mentioned. It is an important fact that the double integral is identically equal to the product LL_m. Thus, $k = (1/6)(L/L_m)$.

Correct values of k certainly lie nearer to 1/6 than to 1/3. As stated in my paper, methods of averaging were not therein considered, mainly because space in *Proceedings Am. Soc. C. E.*, must not be devoted to questions not specifically raised in the discussions.

BROOKLINE, MASS.,
September 12, 1931.

Explanatory Remark: The flow is in the positive direction of x, parallel to the xy plane (horizontal), with constant transverse velocity gradient, $a = du/dz$, increasing with $+z$ (upward), as on pp. 974–980 of the paper. Use of the net transfer of momentum through an element of area, ds, $(dx\,dy)$, has been ascribed to Maxwell. This amounts to calculating the total change of motion of all the molecules passing up and down through ds, regardless of the direction of the change. If the signs of these changes are considered, the sum should be zero in Maxwell's mechanism. The writer points out that the changes of motion of only the molecules moving in one direction through ds, should be summed, in order to calculate the impulse upon the gas (free body) on one side of the plane of shear.

If the pole of spherical coördinates is taken at ds, with axis of θ perpendicular to xy, and ϕ is the angle which the projection of polar distance, r, makes with x in the xy plane, then an element of volume dv located at (r, θ, ϕ) is measured by $r^2 \sin\theta\, dr\, d\theta\, d\phi$. The solid angle subtended by ds at dv is $ds \cos\theta \div 4\pi r^2$, In time dt the number of molecules which collide and start new free paths within dv, toward ds, may be found by multiplying the solid angle by $N\bar{z}\, dv\, dt$, N being the molecular density and $\bar{z} = \bar{c} \div L_m$, $\bar{c}$ being the mean molecular velocity, L_m the general mean free path, $\bar{z}$ being *assumed* constant. If m is the constant molecular mass, the density is $\rho = Nm$.

If the total change of motion of all the molecules moving in one direction through ds now be calculated, the formula given above for the coefficient of viscosity results immediately from division by a $ds\, dt$. Any assumption of ψ which gives a fixed value of k is questionable by Theorem II, Art. 5, p. 946. This type factor doubtless depends on mean molecular diameters, distances, etc.

Theory of Similarity and Models

Newtonian similitude forms the original subject of the paper. It is shown that a true dynamic model depends for its accurate operation only upon the materials which compose the similar systems, upon their physical properties, and upon the general conditions under which they must work, but, contrary to common belief, not at all on the size, form, and action of model or prototype.

The writer's equations of similitude furnish a program of technique giving rise to Newtonian Model Engineering, a new branch of general design, theoretically exact, even in cases where no exact analytical theory is known.

The nature of the great lacuna of fluid dynamics is pointed out and examined. It is shown that these sciences are wholly barren in the domain of turbulent flow. The writer thinks this void is not fully appreciated, especially by hydraulic engineers. It can be bridged, with theoretical accuracy, only by Newtonian model engineering, or by constructing the full-sized prototype, and then testing it *in situ*. There is no rational theory of turbulent flow.

Another feature is the classification of the coefficients of a science, as based upon the postulates of the science, showing that all forms of coefficients are eliminated from relations between Newtonian model and prototype. Dynamical science is discussed at some length.

The theory gives the engineer opportunities to use his technical skill in this branch of technique, namely, the construction of theoretically accurate tools for design and research.

An effort has been made throughout to avoid complicated mathematical operations.

REPORT OF THE COMMITTEE ON SECTIONS AND BRANCHES, S. P. E. E., 1930–1931 *

New Branch and Sections Organized

Within the year, one new Branch and two new Sections of the Society have been organized as follows:

1. *The Colorado School of Mines Branch* was organized on October 22d at a meeting called by Dean Jesse R. Morgan, a member of the Committee. Professor R. A. Baxter was elected President; Professor I. A. Palmer, Vice President; and Professor G. W. Salzer, Secretary-Treasurer. Several meetings of the Branch have been held, two of which, on October 22d and on November 12th, have been reported in the Journal.

2. *The Arkansas-Oklahoma Section* was organized at a meeting held at the Oklahoma A. and M. College on February 13 and 14, 1931. This meeting was arranged through the efforts of Dean W. N. Gladson of the University of Arkansas, member of the Committee, Dean Donnell of the Oklahoma A. and M. College and Dean Felgar of the University of Oklahoma. Professor L. C. Price of the University of Arkansas was elected President; Professor G. R. Saxton of the Oklahoma A. and M. College and Professor J. F. Brooks of the University of Oklahoma, Vice Presidents; and Professor W. R. Spencer of the University of Arkansas, Secretary. A comprehensive report of the meeting and several papers presented at the meeting were published in the April number of the Journal.

3. *The Texas Section* was organized at a meeting at the A. and M. College of Texas at College Station on April 3d and 4th, called by Dean F. C. Bolton, member of the Committee. Forty five persons from outside the institution and about forty members of the A. and M. staff attended the meeting. Doctor F. E. Giesecke of the A. and M. College of Texas served as temporary chairman.

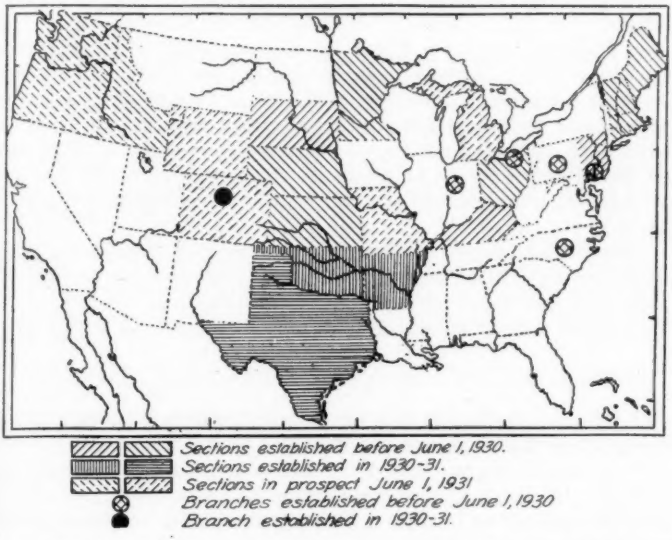
New Sections in Prospect

Other sections in prospect which may be organized soon are as follows:

1. *Colorado-Wyoming Section.*—At a meeting of the Colorado School of Mines Branch last March, a committee was appointed to

* Presented at the 39th annual meeting at Purdue University, June 17–19, 1931.

arrange for a meeting early next fall to which representatives of the University of Colorado, the University of Wyoming, the Colorado Agricultural College, and the University of Denver will be invited with the expectation that an effort will be made to organize a Section at that time.


Sections established before June 1, 1930.
Sections established in 1930-31.
Sections in prospect June 1, 1931
Branches established before June 1, 1930
Branch established in 1930-31.

2. *Northwest Section.*—Dean H. S. Rogers of Oregon had planned to arrange for a meeting this spring of representatives of engineering schools in Oregon, Washington, and Idaho for the purpose of attempting to organize a Northwest Section, but due to an unusual combination of circumstances, it was finally decided to postpone this meeting until next fall.

3. *Michigan Section.*—A Special Committee on a Michigan Section was appointed last fall consisting of:

Director Robert H. Spahr of the General Motors Institute, a member of the Society Committee on Sections and Branches, Chairman,
Dean H. B. Dirks of Michigan State College,
Professor H. H. Higbie of the University of Michigan,
President W. O. Hotchkiss of the Michigan College of Mining and Technology,
Dean R. E. Lawrence of the University of Detroit,
Arthur R. Carr of the College of the City of Detroit, and
Professor R. A. White of the Grand Rapids Junior College.

A conference of members of the engineering faculties of the Michigan institutions will be held in Ann Arbor sometime next fall. Probably no attempt to organize a Michigan Section of the S. P. E. E. will be made at that conference, but it is expected that other similar conferences will be held in the future and it is hoped that these will lead untimately to the organization of a Michigan Section.

4. *Missouri Section.*—Dean A. S. Langsdorf of Washington University in St. Louis, a member of the Committee, has worked this year to promote interest in the organization of a Missouri Section, and has secured the approval of the members at the three institutions, Washington University, the University of Missouri, and the Missouri School of Mines for the formation of the Section. An organization meeting is to be held at Washington University next fall.

Considerable correspondence has been carried on with engineering educators in other states than those mentioned above, relative to the possible organization of other Sections and Branches, but without any further results which need to be reported at this time.

Geographic Distribution of Sections and Branches

A map is attached to this report which shows the present stage of organization of Sections and Branches of the Society.

It is interesting to note from this map how the Sections are grouped. It seems that the contagion or infestation must spread from one state over into the adjoining states, like influenza or the corn borer!

Respectfully submitted,

R. A. Seaton,
Vice President, S. P. E. E.,
Chairman, Committee on
Sections and Branches.

COLLEGE ALGEBRA FOR STUDENTS OF ENGINEERING*

By WILLIAM E. BROOKE

Professor of Mathematics, College of Engineering and Architecture, University of Minnesota

Part I. Course Content

In consequence of the widely varying and generally poor preparation in elementary algebra which the high school graduates have, it is proposed in college algebra:

(*a*) To give a thorough review of algebra from the beginning, stressing definitions, conventions, fundamental concepts and processes; requiring in particular more facility in manipulating fractions, exponents, surds, and also an ability to translate statements into equations.

(*b*) To give those topics in college algebra which are of most importance to the engineer.

Experience has shown that a student who does not have the abilities and skill noted in (*a*) is continually distracted by the elementary operations of algebra. He is unable to concentrate on the fundamental ideas and concepts of analytic geometry or calculus because nearly all of his time, effort, and attention must be given to algebraic operations. A further consequence is that he does not grasp the fundamental notions of calculus and therefore is unable to apply them either in his engineering course or in practical engineering problems.

1. Definitions. Quantity, unit, measure, number. Algebraic expression, term, coefficient, exponent, factor, degree of a monomial, like terms, integral expression, parentheses, axiom.

2. Conventions. Double use of $+$ and $-$ signs. Multiplication sign omitted. Meaning of $5a$ and 26. Abbreviation of $aaaaa = a^5$. Coefficient unity, exponent unity, denominator unity not written but understood. Parentheses used to indicate the order of operations. Meaning of $a \div b \div c$. Distinction between $\sqrt{36 + 64}$ and $\sqrt{36} + \sqrt{64}$, also $\sqrt{9 \times 4}$ and $\sqrt{9} \times \sqrt{4}$, also $(a + b)^2$ and $a^2 + b^2$, also $(ab)^2$ and a^2b^2, etc.

3. Fundamental Operations. Direct and inverse. Definition

* Outlines of two lectures delivered before the mathematics session of the Summer School for Engineering Teachers, University of Minnesota, August 28, 1931.

of addition, addition of a and b, also $6x$ and kx, also $2a^2bx$ and $5abx$. Like terms. Definition of multiplication, multiplication of a by b, division of 3 by 8. Early introduction and use of the number system of algebra.

4. Commutative, Associative and Distributive Laws. Law of Signs. Their meaning. Order of operations. Proofs of $(-) \times (-) = (+)$. Multiplication defined to include law of signs.

5. Laws of Exponents. A consequence of definition and (3). Confidence in their use attained by reverting to concrete cases viz. $a^2 \times a^3 = a^5$ and $(a^2)^3 = a^6$.

6. Division by Zero. Its prohibition has no meaning, infinity not a number, limit process.

7. Factoring, Factor Theorem, L.C.M., and H.C.F. Definition of factor, rational integral expression. Keep quantities in factor form, make free use of parentheses. Include $a^2 + b^2$ and $a + 1$ among the fundamental types. The usual method for $12x^2 - 23x - 24$ to be replaced. Begin L.C.M. and H.C.F. early with numbers, geometric illustration of H.C.F. As a preliminary to the factor theorem divide $x^3 - 7x^2 + 11x - 13$ by $x - a$ until the remainder does not contain x. Degree of a polynomial (in what letters), homogeneous polynomial. *Check all work.*

8. Fractions. The simplification and transformation of fractions and their reduction to L.C.D. accomplished by one rule. Any other operation on a fraction is wrong. The use of *terms of a fraction* confused with *term*. The vinculum in a fraction. Simple way to make the denominator anything, viz. $\frac{3}{7} = \frac{11\ (3/7)}{11} = \frac{4\ 5/7}{11}$. Fundamental operations with fractions. Complex fractions very important. Cancellation leads to $\frac{\cancel{a}+1}{\cancel{a}} = \frac{1}{0} = 1$ or $\frac{\cancel{a}+1}{\cancel{a}} = \frac{1+1}{1} = 2$, also $\frac{\cancel{b}+\cancel{b}}{\cancel{b}-\cancel{b}} = \pm$ and other varieties of "jazz algebra." Order of operations $1 \div 2 \div 3 = ?$ Also $1 \div 2 \times 3 \div 4 + 5 \div 6 - 7 \times 8 \div 9 = ?$ Ability to recognize factors is essential in gaining facility in manipulation of fractions.

9. Simple Equations and easily factored Quadratic Equations. Definition of equation, identity. Solution of equations effected by the use of axioms. Equivalence of equations. If $ab = 0$ either $a = 0$ or $b = 0$. Fractional and literal equations are most important. One equation in two variables. Simultaneous equations, non-independent and inconsistent equations algebraically. Translation of statement problems into algebraic symbols.

10. Involution and Evolution. Integral powers of monomials. Binomial theorem for positive integral powers. Square of poly-

nomial. The n nth roots of any number, principal root. Integral powers or roots of a product or quotient. Square root of perfect square polynomial or of any number. Cube and higher roots by the binomial theorem.

11. Theory of Exponents. Assume the law $a^m \cdot a^n = a^{m+n}$ to hold for fractional and negative exponents, determine their meaning and then define them accordingly. Very important to work many problems like those in Hall and Knight, Wells' Advanced Course and Palmer and Miser.

12. Irrational Quantities. Surds. Imaginaries. Definition of surd in simplest form and its reduction. Fundamental operations with surds. Reduction of surds to the same order. Order of operations. Division of surds accomplished by writing in fractional form and rationalizing the denominator. Properties of binomial surds, square root of binomial surds. Radical equations, extraneous roots, equivalence of equations. Definition of the imaginary unit ($i^2 = -1$), most general form of algebraic number is $a + ib$. Fundamental operations with complex numbers. Fundamental theorem if $a + ib = 0$, then $a = 0$ and $b = 0$.

13. Quadratic Equations. Completing the square, by formula, what are the *two* roots. Quadratic where the unknown is a function of x. Reduction of a quadratic expression to the sum or difference of two squares, max. and min. values of quadratic expression. Statement problems leading to quadratic equation. Theory of quadratic equations, character of the roots. Simultaneous quadratics, usual cases with emphasis on the fact that the general case leads to a quartic.

14. Graphs. Linear and quadratic equations, equivalence of equations, non-independent and inconsistent, pairing the values, interpretation of imaginary values. Plotting $y =$ a cubic, quartic, quintic in x.

15. Ratio Proportion and Variation. Determination of the constants in equations of known form. A good set of problems from physics, mechanics and engineering.

16. Logarithms. Exponential equations, logarithmic plotting, slide rule.

17. Binomial Theorem. (No proof.) Problems of the type $\left\{\frac{\sqrt{2}x^{1/2}}{3y^{2/3}} - \frac{y^{3/4}}{4x^{1/3}}\right\}^{-\frac{1}{2}}$ or $\frac{17a}{\sqrt[3]{4 - 3a^2}}$ to three terms and simplifications as a review of fractional exponents. Approximations of $\sqrt{a^2 - x^2}$ when x is small compared with a, $\sqrt[3]{1 - x^2}$, $\frac{1}{1 + x}$, $\frac{1}{1 - x}$, etc., where x is small.

18. Arithmetic, Geometric, Infinite Geometric Progressions.

Exercises in writing the nth term, reproduction of formulas for nth term and sum of n terms. Treatment of the two formulas as simultaneous equations.

19. Infinite series. Convergence and divergence, write the nth term. Tests for alternating series. Infinite geometric progression, harmonic series, p series. Comparison test, ratio test. No universal criterion. Interval of convergence.

20. Indeterminate forms.

21. Partial fractions.

22. Equations of Higher Degree. Algebraic solution of cubic and quartic. Statement about the solution of quintic. Approximate determination of the real roots of numerical equations of any degree by graphing and trial.

Optional Topics if Time Permits

23. Theory of equations.
24. Summation of series.
25. Annuities.
26. Permutations and combinations.
27. Probability.
28. Theory of elimination.
29. Homer's method and Sturm's theorem.
30. Symmetric functions of the roots of an equation.
31. Determinants.
32. Invariants.
33. Matrices—Tensors.

Part II. Teaching Problems

1. Teacher's function. Study the students, determine what they want to do and use it as a foundation, lead to other ideas, correct wrong ideas, keep them from getting lost in the maze of trial and error, devise and select appropriate learning exercises and add new information, make adequate assignments of new work, motivate the doing of these exercises, provide inspiration for attacking new problems. Modern ideas: if you can teach, you can teach anything; pass the student or he will acquire an inferiority complex; make your grades fit the bell-shaped curve.

2. Change attitude of student. Change from "getting by" to "I am getting it"—from expecting grade A for doing very little to I want to know more about it—from an occasional memory task to a thinking things through and through—from reliance on teacher or fellow to trust no one but yourself—from doing a few short problems to the enormous amount of labor necessary to learn

algebra—from blindly following a rule to knowing what is happening at each step—from learning a way of connecting a mechanical manipulation with a process to learning fundamental principles—from imitating or following a pattern to thinking of the laws that permit the operations—from a painful lack of facility and correctness in the simple everyday processes to an understanding and a facility in arriving at a result—from dreading the enormity of the job to an enthusiastic satisfaction that you are getting somewhere.

3. Algebra. Its fundamental importance. Basis for all subsequent mathematics, physics, mechanics, engineering. Its study requires much detail and great labor. Its fundamental principles are few. The student must learn them for himself. Systems of teaching or syllabi or schemes are not important. Difficulty of generality of symbols overcome by growth. The steps in solving a problem are the means of arriving at a conclusion. Ten well graded problems better than a thousand. Student must discover his own way of doing them.

4. Definitions, Conventions, and Fundamental Operations are most fundamental. Some definitions inadequate. An insight into how it works precedes a logical proof. Definitions of addition, factor, division, symbolic operations e.g. 3/8, $\sqrt{-1}$. Proof of $(-)\times(-)=+$, definition of multiplication, laws of algebra, order of operations most important. Importance of early introduction of the number system, factors of $a^2 + b^2$, imaginary unit, division by 0.

5. Fractions, Exponents, Radicals are the most important subjects in algebra. The laws are few and easily stated. The student must learn the detailed work himself. An aid to fractions is more factoring and a loosening up of factoring by introducing imaginaries. Difficulty of $a^{3p-2} \times a^{7-5q}$ met by concrete case $a^2 \cdot a^3 = a^5$. Do not speak of *terms* of a fraction, or cancellation. More complicated problems in exponents and radicals. Order of operations continually questioned.

6. Equations. Insist on the axiom back of the transformation. Early introduction of equivalence of equations. Always have a literal coefficient or term in the equation. Check all roots instead of looking up answers. Character of roots and equivalence of equations made clear by graphs. Statement problems should be easy numerical ones followed immediately by literal quantities.

7. Ratio, Proportion, Variation. Much of old phraseology omitted, proportion treated as fractional equation. Variation immediately changed to an equation with undetermined constant. Problems from physics and engineering.

8. Logarithms. Emphasize that logarithm is an exponent. Knowledge of logarithms more important than use of tables. Insist on proof of laws of logarithms. Problems like these, find x where

$x = 25 \times \log 7$, $x = \log 25 + \log 7$, $x = \log (25 + 7)$, $x = \log \frac{25}{7}$, $x = \frac{\log 25}{\log 7}$, $x = \sqrt[7]{\log 25}$, $x = \log \sqrt[7]{25}$, $x = 7 \log x$, $\log x = \frac{7}{\log 25}$, $\log x^7 = 25$, $\log^2 x + 7 \log x = 25$, $x = (.025)^{.007}$.

9. Binomial Theorem. Used for approximations, review of fractional exponent simplification and as a rule for extracting roots.

10. Infinite series. Use infinite geometric progression and harmonic series as an introduction. Insist on alternate series, p series and ratio test as a minimum.

11. Numerical Equations of higher degree. An easily remembered method of solution is superior to Horner's.

ANALYTIC GEOMETRY FOR STUDENTS OF ENGINEERING *

By WILLIAM J. BERRY

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Part I. Course Content

A. Analytic Geometry of Two Dimensions

I. The historical development of the subject.
   1. Appolonius of Perga—study of the conic sections by Euclidean methods.
   2. Descartes and the introduction of coördinates—an easier and more effective way of solving the problems of Appolonius.
   3. Conic Sections—the content of the courses formerly given in the English universities as represented by the works of such authors as Salmon and C. C. Smith.
   4. The expanding problem—variety of coördinate systems and the study of curves other than conics.

II. Delimiting the extent of the course:
   1. As to the nature of its elements—a point geometry;
   2. As to the character of its postulates—a Euclidean geometry;
   3. As to the dimensionality of its space—an R_2;
   4. As to its emphasis—on methods rather than on facts, the purpose being to develop power rather than to increase information.

III. Coördinate systems.
   A. Those which should be studied in detail:
      1. Rectangular coördinates.
      2. Polar coördinates.
      3. Oblique coördinates (somewhat less thoroughly than the first two).
   B. Systems which might be mentioned and briefly described:
      1. Trilinear coördinates.
      2. Homogeneous coördinates.
      3. Areals.

* Outlines of two lectures delivered before the mathematics session of the Summer School for Engineering Teachers, University of Minnesota, August 31, 1931.

4. Barycentric coördinates.
5. Curvilinear coördinates.
6. Simple and double logarithmic coördinates.
7. Parametric representation.

C. The equations of transformation for passing in either direction between the rectangular and polar systems.

IV. The point—its representation.
1. In rectangular coördinates.
2. In oblique coördinates.
3. In polar coördinates (note that the representation is not 1 : 1 both ways).

V. Two points—the line segment.
1. Its position—determined by the coördinates of its end-points.
2. Its length—the distance formula.
a. In rectangular coördinates.
b. In oblique coördinates.
c. In polar coördinates.
3. Its direction—inclination, slope and the slope formula in rectangular coördinates.
4. The angle between two line segments. Special conditions for perpendicularity and parallelism.
5. Points of division—the formulas both in rectangular and in oblique coördinates, with the midpoint formulas as special cases.

VI. Three points—the triangle.
1. The area formula.
a. In rectangular coördinates.
b. In polar coördinates.
2. The determinant form—condition for the collinearity of three points.
3. Special case of the triangle with one vertex at the origin.
4. Generalization of the theory to the case of any plane polygon.

VII. Application of analytic methods involving the use of formulas mentioned above to the solution of more or less familiar problems of Euclidean plane geometry. The centroid formulas.

VIII. The fundamental problems.
A. To find the equation of a locus:
1. When the data are in terms of coördinate geometry.
2. When the data are purely Euclidean.
a. The choice of axes.
b. The representative point.

c. Auxiliary variables.
d. Parametric representation.

B To find the locus of an equation—curve analysis
1. In rectangular coördinates.
   a. Tests for symmetry.
      α. About the X-axis.
      β. About the Y-axis.
      γ. About the origin.
      δ. About the 45° line.
      ϵ. About the 135°-line.
   b. Intercepts.
      α. On X-axis.
      β. On the Y-axis.
      γ. On the 45° line.
      δ. On the 135° line (when the last two are axes of symmetry).
   c. Asymptotes.
      α. Parallel to the X-axis.
      β. Parallel to the Y-axis.
   d. Extent.
2. In polar coördinates.
   a. Symmetry
      α. About the polar axis and its extension through the pole.
      β. About the 90° line.
      γ. About the pole.
   b. Intercepts
      α. On the polar axis and its extension through the pole.
      β. On the 90° line.
   c. Extent.
3. Illustrations, which for the case of rectangular system might well include the conics. Examples from polar coördinates might include such common curves as the spirals, limaçons rose-curves and lemniscate. The cyclic-harmonic curves are an interesting generalization and serve to show the effect on the locus of altering the relations between the constants of the equation.

C. The problem of the intersection of two curves—the algebraic problem of simultaneous equations. It should here be pointed out that in polar coördinates, intersection in the geometrical sense does not necessarily imply the identity of the values of both ρ and θ for the two curves at the point in question.

IX. The right line and the linear equation.

1. Forms of the right line equation in rectangular coördinates.

a. The two point form,

$$\frac{y - y_1}{x - x_1} = \frac{y_2 - y_1}{x_2 - x_1}.$$

b. The intercept or symmetric form,

$$\frac{x}{a} + \frac{y}{b} = 1.$$

c. The determinant form,

$$\begin{vmatrix} x, & y, & 1 \\ x_1, & y_1, & 1 \\ x_2, & y_2, & 1 \end{vmatrix} = 0.$$

d. The point-slope form,

$$y - y_1 = m(x - x_1).$$

e. The slope-intercept form,

$$y = mx + b.$$

f. The normal form,

$$x \cos \alpha + y \sin \alpha = \rho.$$

g. The general form

$$Ax + By + C = 0.$$

A. This equation always represents a right line, and conversely every right line may be represented by an equation of this form.

B. The difference between this equation and the forms

$$x + B'y + C' = 0,$$
$$A''x + y + C'' = 0,$$
$$A'''x + B'''y + 1 = 0.$$

2. Forms of the right line equation in polar coördinates.

a. The special families,

$$\rho = a \sec. \theta,$$
$$\rho = b \csc \theta,$$
$$\theta = \text{const.}$$

b. The normal form,

$$\rho = p \cos (\theta - \alpha).$$

c. The two point and determinant forms as obtained by the transformation of coördinates.

3. The normalizing process and its applications,
   a. To the distance between two parallel lines,
   b. To the distance between a point and a line,
   c. To the determination of the bisectors of the angles formed by two lines.
4. Systems of right lines.
   a. Systems of parallels.
   b. Pencils of right lines—the form $\lambda_1 L_1 + \lambda_2 L_2 = 0$ including the angle bisectors for the case

$$\frac{\lambda_2}{\lambda_1} = \pm 1$$

and normal forms for L_1 and L_2.

X. The Circle.

1. Forms of the circle in rectangular coördinates.
   a. The circle referred to its center,

$$(x - a)^2 + (y - b)^2 = r^2.$$

   b. The circle about the origin (canonical form)

$$x^2 + y^2 = r^2.$$

   c. The circle referred to a diameter and the tangent at its left-hand extremity,

$$x^2 + y^2 = 2rx.$$

   d. The three point form,

$$\begin{vmatrix} x^2 + y^2, & x, & y, & 1 \\ x_1^2 + y_1^2, & x_1, & y_1, & 1 \\ x_2^2 + y_2^2, & x_2, & y_2, & 1 \\ x_3^2 + y_3^2, & x_3, & y_3, & 1 \end{vmatrix} = 0.$$

   e. The general form,

$$x^2 + y^2 + Dx + Ey + F = 0.$$

   α. The conditions that this equation represent a circle, a point, or no locus.
   β. Every circle may be respresented by an equation of this form.

2. Forms of the circle equation in polar coördinates:
   a. The circle referred to its center,

$$\rho_1^2 + \rho^2 - 2\rho\rho_1 \cos (\theta - \theta_1) = r^2.$$

b. The center on the polar axis,

$$\rho_1^2 + \rho^2 - 2\rho\rho_1 \cos\theta = r^2.$$

c. The pole on the circumference,

$$\rho = 2r \cos(\theta - \theta_1).$$

d. The circle through the pole with its center on the polar axis,

$$\rho = 2r \cos\theta.$$

e. The circle about the pole,

$$\rho = \text{const.}$$

f. The three point form as obtained by the transformation of coördinates.

3. Systems of circles of the form $\lambda_1 K_1 + \lambda_2 K_2 = 0$, including the radical axis for the case $\frac{\lambda_2}{\lambda_1} = -1$. Radical centers.

4. The length of a tangent from an external point.

XI. Transformations of the plane:

1. Translations,

$$x = x' + h,\ y = y' + k.$$

2. Rotations,

$$x = x' \cos\theta - y' \sin\theta,$$
$$y = x' \sin\theta + y' \cos\theta.$$

3. Rigid motions,

$$x = x' \cos\theta - y' \sin\theta + h,$$
$$y = x' \sin\theta + y' \cos\theta + k.$$

The succession of a translation and a rotation (or the reverse) is a rigid motion.

4. Group properties of the transformations,
   a. In each case, the succession of two is equivalent to a third of the same kind.
   b. In each case, the inverse transformation exists,
   c. Each admits of the identical transformation.
5. Non-rigid motions (examples briefly described):
   a. Reflections.
   b. Dilatations.
   c. Inversions.
   d. Polar reciprocations.

6. Path curves, fixed points and lines, lines of fixed points.
7. The use of transformations for simplifying equations.

XII. The general equation of the second degree.

1. Degenerate conics.
   - *a*. The analytic condition for degeneracy—the vanishing invariant.
   - *b*. Methods for obtaining the constituent lines,
     - α. By rotation and translation.
     - β. By direct solution of the equation as a quadratic in either variable.
2. The translation and its use in classifying conics—the second invariant. The reduction of a central conic to canonical form by formulas.
3. Non-central conics. Reduction to canonical form.
   - *a*. By rotation and translation.
   - *b*. By the λ-method.
4. General discussion of a second degree equation:
   - *a*. Identification of the locus by means of the invariants.
   - *b*. Reduction to canonical form.
   - *c*. Graphing of the curve and all the axes used.
   - *d*. Checking by means of the intercepts on the original axes.

XIII. Tangents, normals, diameters and asymptotes.

1. Definitions.
2. Tangents at a point on a curve:
   - *a*. The general method—its limitations.
   - *b*. The tangent to the general conic and the formal rules for deriving it from the equation of the curve.
   - *c*. Special cases:
     - α. for the circle, $x_1x + y_1y = r^2$.
     - β. for the ellipse $\frac{x_1x}{a^2} + \frac{y_1y}{b^2} = 1$.
     - γ. for the hyperbola $\frac{x_1x}{a^2} - \frac{y_1y}{b^2} = 1$.
     - δ. for the parabola $y_1y = p(x + x_1)$.
3. The tangent in terms of its slope—the general method. Special cases:
   - *a*. For the circle $y = mx \pm r\sqrt{1 + m^2}$.
   - *b*. For the ellipse $y = mx \pm \sqrt{a^2m^2 + b^2}$.
   - *c*. For the hyperbola $y = mx \pm \sqrt{a^2m^2 - b^2}$.

d. For the parabola $y = mx + \frac{p}{2m}$.

4. The diameters of the conics:

a. For the ellipse $y = -\frac{b^2x}{a^2m}$.

b. For the hyperbola $y = \frac{b^2x}{a^2m}$.

c. For the parabola $y = \frac{p}{m}$.

d. Conjugate diameters

α. Definition.

β. Condition in case of the ellipse,

$$mm' = -\frac{b^2}{a^2}.$$

γ. Conditions in case of the hyperbola

$$mm' = \frac{b^2}{a^2}.$$

δ. Theorems concerning conjugate diameters.

e. Asymptotes—the general rule.

XIV. Special properties of conics.

1. Focal properties.
2. Properties relating to tangents
   a. At a point on a curve.
   b. From an external point.
   c. The pedal curve of a parabola with respect to the focus.
   d. Tangents at right angles to each other—director circles.
   e. Auxiliary circles.
3. Problems of construction dependent upon analytic facts.
   a. To draw tangents to conics at points on the curves.
   b. To draw tangents to conics from external points.
   c. The outline problems.

XV. Polar Coördinates.

1. Plotting simple curves:
   a. The rose curves.
   b. Limaçons of Pascal.
   c. The lemniscate.
   d. The spirals.
   e. Composite curves.

2. Cyclic-harmonic curves—a brief reference showing how changing the values of the constants in an equation will affect the nature of the locus.

XVI. Special and empirical curves.
1. Higher plane algebraic curves.
2. Exponential and logarithmic curves.
3. Composite curves.
4. Empirical curves.
5. Approximate graphic solutions.

B. Analytic Geometry of Three Dimensions

I. Extension of the fundamental ideas set forth in A-II* to a three-dimensional continuum.

II. Coördinate systems in R_3: (Extension of A-III)
A. Those which should be studied in detail:
1. Rectangular coördinates.
2. Cylindrical coördinates.
3. Spherical coördinates.
B. Systems which might be mentioned and briefly described
1. Vector coördinates.
2. Tetrahedral coördinates.
3. Homogeneous coördinates.
4. Volumetric coördinates.
5. Barycentric coördinates.
6. Generalized surface coördinates.
7. Parametric coördinates.
C. The equations of transformation for passing in either direction between rectangular and cylindrical coordinates or between rectangular and spherical coördinates.

III. The point—its representation: (Extension of *A*-IV).
1. In rectangular coördinates.
2. In cylindrical coördinates.
3. In spherical coördinates.

IV. Two points—the line segment: (Extension of *A*-V).
1. Its position—determined by its end-points.
2. Its length—the distance formula in rectangular coordinates.
3. Its direction:
a. Direction angles and cosines.
b. The fundamental relation

$$\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1.$$

* Refers to sec. II of Part One.

c. Direction numbers.

4. The angle between two line segments:
   a. The general formula.
   b. Analytic conditions for parallelism and perpendicularity.
5. Formulas for points of division including those for the mid-point as a special case.

V. The plane and the linear equation in three variables (Extension of *A*-IX).

1. Forms of the plane equation:
   a. Normal form,

$$x \cos \alpha + y \cos \beta + z \cos \gamma = p.$$

   b. Point-direction form,

$$(x - x_1) \cos \alpha + (y - y_1) \cos \beta + (z - z_1) \cos \gamma = 0.$$

   c. General form,

$$Ax + By + Cz = 0.$$

   d. The intercept or symmetric form,

$$\frac{x}{a} + \frac{y}{b} + \frac{z}{c} = 1.$$

   e. The three point form,

$$\begin{vmatrix} x, & y, & z, & 1 \\ x_1, & y_1, & z_1, & 1 \\ x_2, & y_2, & z_2, & 1 \\ x_3, & y_3, & z_3, & 1 \end{vmatrix} = 0.$$

2. The normalizing process and its applications:
   a. To the distance between two parallel planes,
   b. To the distance from a point to a plane,
   c. To the plane bisectors of the dihedral angles formed by two planes.
3. Systems of planes
   a. Systems of parallel planes.
   b. Axial pencils of planes, $\lambda_1 S_1 + \lambda_2 S_2 = 0$, including the plane bisectors of the dihedral angles for the case $\frac{\lambda_2}{\lambda_1} = \pm 1$ and normal forms for S_1 and S_2.

c. Pencils of planes, $\lambda_1 S_1 + \lambda_2 S_2 + \lambda_3 S_3 = 0$ and the analytic conditions for concurrency.

4. The angle between two planes or between a line and a plane:
   a. The general formulas.
   b. The analytic conditions for parallelism and perpendicularity.

VI. Surfaces in general.
1. A single equation in R_3 always represents a surface and conversely.
2. Symmetry of surfaces:
   a. About the coördinate planes.
   b. About the coördinate lines.
   c. About the origin.
3. Traces on the coördinate planes.
4. Sections parallel to the coördinate planes.
5. Other sections.
6. Intercepts on the coördinate axes.
7. Analysis of the equation of a surface.
8. Remarks on sketching with particular reference to isometric drawing.
9. Cylinders whose elements are parallel to a coördinate axis.

VII. Curves in general.
1. Curve considered as the intersection of two surfaces.
2. A curve in R_3 is represented by two equations and conversely.
3. Multiplicity of representation.
4. Projecting cylinders.
5. Graphic representation of curves in R_3. Intersections. (Tie in with drawing course.)

VIII. The right line in three-space.
1. Forms of its equation:
   a. The general form,

$$A_1x + B_1y + C_1Z + D_1 = 0,$$
$$A_2x + B_2y + C_2Z + D_2 = 0.$$

   b. The projection form,

$$y = mx + b,$$
$$z = nx + c.$$

c. The point-direction form

$$\frac{x - x_1}{\cos \alpha} = \frac{y - y_1}{\cos \beta} = \frac{z - z_1}{\cos \gamma} \quad \text{or}$$

$$\frac{x - x_1}{l} = \frac{y - y_1}{m} = \frac{z - z_1}{n}.$$

d. The two-point form,

$$\frac{x - x_1}{x_2 - x_1} = \frac{y_2 - y_1}{y_2 - y_1} = \frac{z - z_1}{z_2 - z_1}.$$

e. Geometrical interpretations.

2. Projections and pierce-points.

IX. Locus problems in R_3 (Extension of *A*-VIII).

X. Special surfaces:

1. Surfaces of revolution.
2. The conicoids—canonical forms:

a. The general ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1,$$

including the spheroids

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} + \frac{z^2}{c^2} = 1,$$

prolate for $a < c$,
sphere for $a = c$,
oblate for $a > c$.

b. The elliptic hyperboloid of one sheet

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1,$$

including the hyperboloid of revolution of one sheet

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} - \frac{z^2}{c^2} = 1.$$

c. The elliptic hyperboloid of two sheets

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1,$$

including the hyperboloid of revolution of two sheets

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{b^2} = 1.$$

d. The elliptic paraboloid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - 2pz = 0,$$

including the paraboloid of revolution,

$$\frac{x^2}{a^2} + \frac{y^2}{a^2} - 2pz = 0.$$

e. The hyperbolic paraboloid

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - 2pz = 0.$$

3. Ruled surfaces, especially the ruled conicoids (*b*, *e*).
4. Cones, especially the quadratic cone.

Part II. Teaching Problems

1. How shall the desired material be condensed into a course of average length?
   - *a.* By concentrating on the acquirement of methods rather than factual information.
   - *b.* By assigning some of the material often presented in lectures as problems for original work.
   - *c.* By assigning certain sections or chapters as collateral reading.
2. How can students be given an understanding and appreciation of the underlying and unifying principles?
   - *a.* By carefully worked out topical analysis outlines.
   - *b.* By schematic diagrams showing the interconnection of the various topics treated in the course.
   - *c.* By careful analyses of illustrative problems on the basis of the fundamental principles involved.
3. How can students be led to think simultaneously in terms of geometry and of analysis?
   - *a.* By insisting that the solution of every problem be accompanied by a complete and accurate figure.
   - *b.* By demanding that analytic results be checked against such a figure.

c. By following this procedure in connection with every problem solved in class, even when it is possible for one experienced in analytic geometry to dispense with the figure.

4. How can the work in analytic geometry be coördinated with the instruction in other subjects, particularly English, drawing, physics and engineering?

a. By insistence on accurate, clean-cut grammatical statement of definitions and theorems. By requiring that all questions be formulated properly. The teacher himself should guard against any carelessness or slovenliness in speech.

b. By pointing out the parallelism between the processes of the draughting room and the steps in an analysis. The instructor should make his own drawings carefully calling attention from time to time to the principles of draughting involved, especially necessary in connection with problems in the analytic geometry of three dimensions.

c. Such topics as transcendental equations, empirical equations and approximate graphic solutions permit the use of illustrative examples from those parts of physics with which the student may reasonably be supposed to be familiar.

d. Since analytic geometry is usually a freshman course and the freshman can scarcely be expected to know much about the technical side of engineering, it is doubtful if much can be done toward establishing connections here.

5. Should the elements of the calculus and its notation be introduced into a course in analytic geometry?

a. This is a moot question. Weighty and authoritative opinion can be cited in support of either side.

b. Arguments pro—

1. It simplifies and generalizes the problem of tangents.
2. It supplies added useful information for the problem of curve tracing.
3. It permits of a more extended treatment of the three-dimensional geometry.

c. Arguments con—

1. Time does not permit of any considerable profit from these advantages.
2. Time does not permit of laying a firm foundation

for the calculus or a proper justification of the processes employed.

3. The new ideas inherent in analytic geometry of themselves give enough trouble to the student without adding those basic in the calculus.

6. How shall the necessary drill be secured in the time allotted?
   - *a*. Board work.
   - *b*. Problem work, handed in, corrected, graded, and returned.
   - *c*. Problem work, turned in, but neither corrected nor graded—perhaps not even read.
   - *d*. Definite problem assignments made, but without the requirement that the solutions be submitted.
   - *e*. Quizzes
     - Daily.
     - Weekly.
     - Less frequently.

7. What proportion of the time should be allotted to the study of three-dimensional geometry?

MEMBERSHIP CAMPAIGN FOR 1931–32

October 5, 1931

To the Members of the Society:

Will you secure at least one new member for 1931–32?

Last year, through the coöperation of the members we added 235 new members to the rolls of the Society. With your assistance we can exceed that number this year. We are enclosing an application blank for your convenience and shall be glad to send you as many more as you may desire. If you need a blank before we could get it to you, ask your Dean to let you have one of his. We are sending a supply of application blanks to each Dean just for emergencies like this.

Beginning with the November JOURNAL we shall publish the list of institutions with the number of members in each and the number of applications received from each. We shall correct this each month thereafter. By this method you will be kept informed of the progress your institution is making in enrolling its staff in this Society.

The dues are $5.00 per year. There is no initiation fee and subscription to the JOURNAL OF ENGINEERING EDUCATION is included in the dues. Have the applicant fill out the blank, make out a check for dues—made payable to the S. P. E. E.—secure two sponsors, and return this to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa. We will then present his name to the Council for election and notify him as soon as possible. However, his subscription, if check for $5.00 accompanies the application, begins with the September number of the JOURNAL.

Trusting we may again have your coöperation, I am,

Cordially yours,

F. L. BISHOP,
Secretary.

102 new members added this year.

MEMBERS IN ENGINEERING SCHOOLS AND COLLEGES

Institution	Members Nov. 3, 1931	Applications Received after Nov. 3, 1931
Akron, Univ. of	9	
Alabama Poly. Inst.	13	
Alabama, Univ. of	2	
Alberta, Univ. of	3	
Antioch College	2	
Arizona, Univ. of	8	
Arkansas, Univ. of	11	
Armour Inst. Tech.	27	
Beirut, Univ. of (Syria)	1	
Bombay C. E. College	1	
Bradley Poly. Inst.	2	
Brazil-Poly. School of State	1	
British Columbia, Univ. of	4	
Brooklyn Poly. Inst.	21	
Brown Univ.	9	
Bucknell Univ.	13	
Buffalo, Univ. of	1	
Butler Univ.	1	
Calif. Inst. Tech.	8	
Calif., Univ. of	15	
Calif., Univ. of So.	6	
Carnegie Inst. of Tech.	14	1
Case School of Applied Science	29	
Catholic Univ.	1	
Cincinnati, Univ. of	6	1
Clarkson College	8	
Clemson College	10	
Colby College	1	
Colorado Agri. College	6	
Colorado School of Mines	10	
Colorado, Univ. of	19	
Columbia University	28	1
Connecticut Agri. College	1	
Cooper Union	14	
Cornell University	28	
Cornell College	1	
Dartmouth College	4	
Dayton, Univ. of	6	1
Delaware, Univ. of	8	
Denison Univ.	2	
Denver, Univ. of	1	
Detroit University	14	
Drexel Institute	8	
Duke Univ.	7	
Duluth Jr. College	2	
Ecole Polytechnique	7	
Ely Jr. College	1	
Escuela Centrale de Ing. Ind.	1	
Evansville College	3	
Fenn College	12	
Florida, Univ. of	7	
Franklin and Marshall	1	
Franklin Union	2	
Fresno Teachers College	0	1
General Motors Inst.	5	
George Washington Univ	3	
Georgia Inst. of Tech.	15	
Gettysburg College	2	
Ghent, Univ. of	1	
Girard College	1	
Harvard University	16	
Haverford College	2	
Hawaii, Univ. of	3	
Howard Univ.	3	
Idaho, Univ. of	12	2
Illinois, Univ. of	54	
Indiana Univ.	1	
Iowa State College	38	
Iowa State University	23	2
James Millikan Univ.	2	
John Tarleton Agri. College	1	
Johns Hopkins Univ.	3	
Joliet Jr. College	1	
Kansas State College	42	1
Kansas, Univ. of	18	
Kentucky, Univ. of	10	
Lafayette College	12	2
Lawrence College	1	
Lehigh Univ.	15	
Leningrad Poly. Inst.	1	
Lewis Inst.	1	
La. Industrial Inst.	1	
La. Southwestern Inst.	2	
La. State Univ.	2	
Louisville, Univ. of	16	
Lwow, Poly. of	1	
Maine, Univ. of	21	3
Manhattan College	7	
Marine Union Jr. College	1	
Marquette Univ.	10	
Marshall College	1	
Maryland, Univ. of	1	
Mass. Agri. College	1	
Mass. Inst. Tech.	45	2
McGill Univ.	9	
Mechanics Inst.	2	
Mercer College	1	
Mexico, Univ. of	2	
Michigan College Mines	5	

Institution	Members Nov. 3, 1931	Applications Received after Nov. 3, 1931
Michigan, Univ. of	47	
Michigan State College	11	
Minnesota, Univ. of	70	1
Mississippi A. & M.	4	
Missouri School Mines	10	
Missouri, Univ. of	17	1
Modesto Jr. College	1	
Montana School of Mines	11	
Montana State College	3	
Mt. Allison Univ.	2	
Nanking Tech. College	1	
Nebraska, Univ. of	24	
Nevada, Univ. of	3	
Newark College of Eng.	13	
New Hampshire, Univ. of	11	
New Mexico A. & M.	3	
New Mexico School Mines	1	
New Mexico, Univ. of	3	
New York, College of City	7	1
New York Univ.	18	1
North Carolina State College	9	
North Carolina, Univ. of	11	
North Dakota, Agr. College	3	
North Dakota, Univ. of	4	
Northeastern Univ.	20	1
Northwestern Univ.	7	
Notre Dame, Univ. of	1	
Norwich Univ.	3	
Nova Scotia Tech. College	1	
Ohio No. Univ.	2	
Ohio Mechanics Inst.	2	
Ohio State University	56	
Ohio University	1	
Oklahoma A. & M.	13	
Oklahoma, Univ. of	7	
Oregon State College	16	
Oregon Inst. Tech.	1	
Pasadena Jr. College	4	
Pei Yeng Univ.	2	
Penna. Military College	2	
Penna. State College	37	
Penna., Univ. of	15	1
Philippines, Univ. of	1	
Pittsburgh, Univ. of	26	
Porto Rico, Univ. of	3	
*Pratt Institute	33	4
Princeton University	12	
Purdue University	87	2
Rensselaer Poly. Inst.	13	
Rhode Island State College	5	
Rice Institute	7	
Rindge Tech. School	1	
Riverside Jr. College	1	
Robert College	5	
Rochester, Univ. of	3	
Rose Poly. Inst.	9	
Rutgers Univ.	14	
St. Thomas, College of	1	
Santa Clara, Univ. of	1	
Saskatchewan, Univ. of	2	
South Carolina, Univ. of	1	
South Dakota School Mines	11	
South Dakota State Coll.	2	
South Dakota, Univ. of	3	1
Southern Methodist Univ.	5	
Stanford University	14	
Stevens Inst. Tech.	13	
St. John's Univ.	1	
Swarthmore College	6	
Syracuse Univ.	14	
Tangshan Univ.	1	
Tennessee Poly. Inst. of	2	
Texas Agri. College	2	
Texas A. & M.	23	
Texas College of Arts	1	
Texas College Mines	1	
Texas Tech. College	14	
Texas, Univ. of	12	
Toledo, Univ. of	4	
Toronto, Univ. of	9	
Trinity College	1	
Tufts College	18	
Tulane University	9	
Tulsa, Univ. of	1	
Union College	10	
U. S. Military Academy	3	
U. S. Naval Academy	7	
Utah Agri. College	2	
Utah, Univ. of	9	
Valparaiso Univ.	1	
Vanderbilt University	5	
Vermont, Univ. of	10	
Villanova College	1	
Virginia Military Inst.	7	
Virginia Poly. Inst.	15	
Virginia, Univ. of	13	
Washington State Coll.	9	
Washington Univ. (St. Louis)	13	3
Washington, Univ. of	16	
Wentworth Institute	5	
West Virginia Univ.	10	
Wisconsin, Univ. of	34	
Worcester Poly. Inst.	27	
Wyoming, Univ. of	7	
Yale University	38	

* Faculty 100% members of S. P. E. E.

Return to the Secretary, F. L. Bishop, University of Pittsburgh, Pittsburgh, Pa.

Society for the Promotion of Engineering Education

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THE PLACE OF THE WORK SCHEDULE IN A COÖPERATIVE ENGINEERING PROGRAM

By R. E. ROBB

Director of Student Personnel and Coordination, General Motors Institute of Technology, Flint, Michigan

Coöperative engineering, by its very name, indicates a duality of purpose. The philosophy underlying the Coöperative Engineering movement in education is that neither the training in the class room nor the experience which the individual can secure on the job is of itself sufficient to give the most reliable foundation on which the young engineer can build for the future. But the proper combination of these two factors is found to give results which are highly beneficial.

If the work experience is considered to be an integral part of the student's training, it behooves the educator to make sure that it is conducted in such a way that the student will really receive the expected benefits. In order to do this it is necessary that this experience be received in an orderly and progressive fashion. The most satisfactory way to secure the desired result is to prepare a definite plan for job sequences. This is called a Work Schedule. By means of this schedule it becomes possible for the student to receive his practical experience in the order calculated to give him the maximum benefit, to spend the correct relative amounts of time on the various parts of this experience, and to avoid being "pocketed" in a production job where he may be making money for the company but where he does not receive the training which he should be getting.

There are certain fundamental elements which should be considered in the preparation of any Work Schedule. The economics of the matter must be given careful consideration. In general the student by the time he graduates should have earned all the wages which he has received during his coöperative employment. This is essential if the training program is to continue on a sound basis. The needs of the plant in which the student is working must also be taken into consideration, and the training program arranged to supply graduates with training for which there will be a demand. The departments available for training in the plant in question must also be given some thought, and in some cases it may be necessary to take into account the personnel in charge of these departments.

Just as educators in the class room vary in effectiveness, so do educators in the shop.

As the student is the person most vitally affected by this work program, his individuality must be considered as much as possible. In general his special abilities and interests will not be known until the latter part of his course. As soon as they do become apparent, the Work Schedule should be so modified as to get him started in the kind of work which offers the greatest promise for the future, both from the standpoint of the student's interest, and also from that of plant requirements.

It will be apparent from the above that the Work Schedule must be flexible. It not only must take account of the trend of development of the student, but varying plant conditions must be allowed for. In practice it is usually not vitally important that the order of jobs in the Work Schedule be rigidly adhered to in all cases. A little give and take is found to be advantageous all around, but this does not in any way minimize the importance of having the general plan.

In order for the student to receive maximum benefit from even the best Work Schedule, however, it is necessary that he give careful study to his job while working on it. One of the most effective ways yet found to secure this result is to require a Coördination Report from the student for each work period. The coördination report subjects should of course be closely related to the job on which the student is working.

The writer's experience with Work Schedules has been most satisfactory. In fact it is felt that there would be a very distinct loss in operating a coöperative engineering school without them. When every man has a definite training program which is yet sufficiently flexible to meet practical requirements, he is assured of receiving maximum benefits from his shop experience. The coordination reports which he writes open his eyes to knowledge and opportunities of which he would otherwise be oblivious. The two, combined with the necessary technical courses, go far in giving the student the preparation which he needs for meeting the problems of modern industry.

DISCUSSION OF COÖPERATIVE RESEARCH

I read with a great deal of interest the articles by Dean Potter and Director A. E. White on coöperative research. I feel that they have covered the situation very nicely, pointing out not only its advantages but some of the difficulties that we run into as these investigations become more numerous and larger in scope.

One difficulty which I believe we have overcome here at the University of Illinois in the Chemical Engineering Division may be of interest to you and your readers. That is the problem of adequate direction of coöperative research. As has been pointed out before, it is difficult for the ordinary staff man to find sufficient time to give a particular coöperative investigation. In fact the chief criticism that I have heard from the industry has been due to this very reason;—the coöperative investigation has not received careful enough consideration by the staff man. In order to eliminate this difficulty we have in the Chemical Engineering Division here at the University of Illinois made it a point to accept only such coöperative investigations which are broad enough and important enough to justify the hiring of a new staff man to take complete charge of the investigation. The full-time, well-trained, experienced man with adequate help in the form of mechanics, graduate and undergraduate students will naturally accomplish more than will an overburdened staff man attempting to do the same thing with half-time workers, inexperienced and inadequately trained.

The problem, if carried out along these lines, has an excellent chance for success if one is careful and fortunate in the selection of the new staff man to head the research. At least such has been our experience here at Illinois in this division.

D. B. KEYES,
Professor of Industrial Chemistry

ENGLISH AS AN ESSENTIAL PART OF THE ENGINEERING CURRICULUM

By A. V. HALL

Associate in English, University of Washington

The concise four-year curriculum of the colleges of engineering makes imperative good utilization of every credit-hour, in order that the students graduated at its close may have reached the exacting standards of specialization and in addition may have obtained that broad acquaintanceship with the needs and interests of their contemporaries proper to the professional man of our day. At the University of Washington, careful planning and experimentation on the part of both the engineering faculty and the department of English has resulted in a well-defined procedure by means of which these two objectives should be increasingly furthered through the hours devoted to English.

Broadly, the distinguishing features of this procedure are (1) segregation of the engineering students, (2) postponement of the course in composition until near the beginning of the junior year, with a coöperative arrangement by which certain lower-division technical papers are corrected by the English instructors, mainly as an aid in eradicating errors in grammar, punctuation, and spelling, and (3) introduction of a conference course which permits the individual student to advance at his own rate of speed both in the practice of writing and in the understanding of contemporary thought. Throughout, concerted effort is put forth to make obvious the fact that in the training of an engineer English forms an essential part.

Through the courtesy of the engineering faculty, for the past seven years the engineering English instructors have had offices and classrooms in one of the buildings on the lower campus. Because they teach engineering students only, they are able to revise the materials and methods of the English courses in the light of practical experience, and consequently to shape the work in accordance with actual needs.

The reason for replacing the ten quarter-hours of composition previously required of freshmen by three quarter-hours given at either the close of the sophomore year or some time during the junior year, was the apparent waste of time involved in attempting to teach students who were not as yet interested and who had few ideas

to express. The outcome of the readjustment has proved it wise. By the time men have had two years or so of technical training, they are prepared to use their intellectual powers upon a subject for which they now feel a real need. Moreover, if they have made good use of the opportunity afforded by the comments written upon their returned papers of the two years preceding, when they reach the composition course itself they are prepared to utilize it to best advantage.

The Overcoming of Mechanical Errors

According to the plan adopted for the lower division, two papers each quarter are carefully gone over by the English instructors for every freshman and sophomore student. These papers are written as a regular part of the technical courses, and are corrected and returned as quickly as possible, while interest in them is still keen. The corrections are made in full, a set of rubber stamps contributing to their legibility and to the number of words that may be written in a small space and without loss of time. Lest the student conclude that spelling, punctuation, grammar, and neatness are alone worthy of attention, grades are given for content, organization, sentence-structure, and vocabulary as well.

The working out of this plan for a typical quarter is here presented. The number of freshman students was about 350, of sophomores, about 220.

Technical Papers Corrected for English During One Quarter

Time of Quarter	Year of Student	Courses	Number of Papers
End of first month	Freshman	Gen. Eng. 11, 12, 13	305
	Sophomore	Mech. Eng. 82, 83, and Civil Eng. 131	132
End of second month	Freshman	Chemistry 1, 2, 3	240
		Gen. Eng. 1 and 21	301
	Sophomore	Physics 97, 98, 99	140
Total.....			1118

The great value of this scheme of correction is, first, the evidence it gives the student that his engineering professors consider accuracy and neatness essential in English as well as in drawing and mathematics. This very desirable impression is deliberately intensified by several professors, humorously critical of gross errors occurring during recitation. They alone have power to transform into an

alert concern the attitude of carelessness induced by some high school instructors, who—as, for example, was recently noted in a theme proudly exhibited for its grade of A+—will permit without comment more than half a dozen mistakes in spelling within a single brief paragraph. Without active cooperation on the part of the engineering faculty, the task of eradicating long-established habits of inaccuracy would be almost impossible. With it, the second great value of these lower division papers comes into play, for, once aware of his weaknesses and eager to overcome them, by means of the corrections indicated on his papers—and if he chooses, by personal conference with an English instructor, who has regular office hours for this purpose—the student may steadily improve his English.

That progress has been made during the four-year operation of this schedule is evident upon examination of one hundred papers read just before its adoption, in 1928, and of a second and third hundred read in 1930 and 1931. The only negative result, that of

COMPARISON OF 100 PAPERS IN 1928, IN 1930, AND IN 1931

	1928	1930	1931	Gain Within Four Years	
				In Papers	Percentages
Errors in spelling					
None	25	33	23	−2	−8%
One or two	33	40	61		
Three or more	42	27	16	26	62%
	100	100	100	24 papers out of 100	
Errors in punctuation					
None	11	24	42	31	28%
One or two	36	55	53		
Three or more	53	21	5	48	90%
	100	100	100	79 papers out of 100	
Errors in grammar					
None	11	44	45	34	301%
One or two	34	43	47		
Three or more	55	13	8	47	85%
	100	100	100	81 papers out of 100	

the two fewer papers rating 100 per cent in spelling, is more than offset by the 54 papers misspelling fewer words. Of the 100 papers read in 1931, 24 showed improvement in spelling over those of 1928, 79 showed improvement in punctuation, and 81 in grammar. Some

of this gain is of course attributable to the better training now being given in secondary schools, some also perhaps to the higher caliber of the present student engineer. But, whatever may be their full explanation, the results most assuredly indicate a growing consciousness of correct form.

Still further indication is given by comparison of the percentages of students passing the test for admission to the course in composition during the past six years. This test is taken by filling in three mimeographed sheets, of foolscap size, and writing a theme of about 500 words. On the first sheet the student letters sentences dictated for spelling; on the second he inserts omitted marks of punctuation and capital letters; on the third he underlines the grammatical forms correct for the sentences given. His theme is judged simply on the score of correctness in spelling, punctuation, and grammar, for experience has shown that failure in these respects most often necessitates a drill period longer than that allowed by the three-hour course. Accordingly, before he may enter it, a student who fails is obliged to obtain a passing grade either in a test of later date or in a non-credit course in the mechanics of writing, introduced for the purpose.

When the test was first given, in the spring of 1926, the standard adopted was less stringent than it is at present; nevertheless the proportion of students passing the test has not in general decreased, as is shown by the table below, which also presents the increasing percentages of passing grades obtained in the composition course itself during the same period.

PERCENTAGES OF STUDENTS OBTAINING PASSING GRADES

(Year)	In the Admission Test	In the Course
1926, Spring	73%	59%
1926–27	75%	65%
1927–28	79%	72%
1928–29	80%	72%
1929–30	83%	82%
1930–31	79%	86%
Gain	6%	27%

All these facts point the conclusion that through the thoughtful coöperation of the engineering faculty—a coöperation further evidenced by the inclusion in their freshman manual of several pages on careful writing—even before the student enters the required course in composition his English has visibly been bettered.

TECHNICAL WRITING

Once entered upon the course itself, the student devotes three credit-hours to intensive study of the logical organization and

effective presentation of technical articles, reports, and business letters. If he is a chemical engineer, this completes his requirement in English. Within the brief span of thirty-three or fewer class periods he—and with him the students in other departments—must not only grasp the principles of technical composition, but also apply them as far as he can in practice. The allotment of time is about as follows.

PLAN FOR THE QUARTER'S WORK IN COMPOSITION

Number of Class Periods	Topics
3	Introduction to course; Tests
12	Organization of material Outlining; Short speeches; Written articles, from a paragraph to 1500 words in length
6	Sentence-structure and vocabulary
12	Particular investigations Library research; Writing of 2000-word article; Business letters; Reports
33	

In addition, each student has five half-hour conferences with his instructor during the quarter, for the purpose of clearing up individual difficulties and arranging for the work yet to be covered.

Despite the brevity of the course, the earnest student will learn the advantage of centering his ideas about one specific thesis, and of developing them in logical order, in wording that compels attention. Further, he gains some familiarity with the form in which his later reports will be cast, a matter, as he now begins to realize, likely to be a contributing element in his success as an engineer.

A SECOND QUARTER OF ENGLISH

In all but the one department mentioned, the engineering curricula at Washington include a second quarter of English. In one other, where the number of the required course is not prescribed, advantage may well be taken of a three-hour course in extemporaneous speaking given by the Public Speaking Department for upper-division students other than those in liberal arts. As an elective also, this course is proving very satisfactory, in that the instructor has clearly in mind the characteristic needs of the engineering students, and also limits the size of a class to permit ample opportunity for practice in speaking.

The majority of the curricula, however, prescribe for the second quarter an individual conference course of three credit-hours, given by the instructor in engineering English. Its aim is to supply for each student engineer contact with ideas new to him but suitable

to his degree of mental maturity, and to accustom him to self-expression in writing. He is free to decide for himself the proportion of his nine hours a week to be devoted to the writing. In most cases, unless his intention is to drill intensively in business letters and reports, he elects only the minimum amount of writing—about five hundred words a week—and devotes most of his attention to various types of reading.

At his preliminary conference he is given a mimeographed sheet briefly outlining the whole field of knowledge, by aid of which he is to make out three lists of subjects, (a) those of which he has some slight knowledge, (b) those with which he is unfamiliar, and (c) those, of either type, deemed suitable for investigation during the quarter. Topics most frequently selected are relativity, astronomy and geology, evolution, psychology, economics and sociology, philosophy and religion. Literature is usually added at the suggestion of the instructor, because, except for the few who wish to read the great world writers, the engineering student is likely to regard its study as of small value in his busy life until shown its power to familiarize him with the unlike points of view so essential to understanding and tolerance. Mimeographed lists including world classics and modern continental, English, and American literature are supplied him, with the request that he check the books already familiar. Finally, he is asked to purchase at the University book store one or more volumes from a carefully selected list of books found by experience to contain the books considered to be of greatest value, and to bring with this book to his first regularly scheduled conference a tentative outline of the work to be covered during the quarter. As an aid in planning the latter, he has another mimeographed sheet stating the average attainment of students taking the course. Whether or not his tentative scheme will be carried out, will of course depend upon the best combined judgment of both student and instructor, then and later on.

The written work submitted each week includes a report, however brief, upon each book or article read. Such a report may merely give the main idea of the article or answer questions made out upon it; it may conform to one of several outlines provided, or it may be entirely original. The final assignment is the writing of a formal report covering the whole accomplishment of the quarter. Its summary views the course in perspective; its table of contents apportions to each written paper its due position in this scheme; its body consists of these papers, one of which is expected to have a length of at least fifteen hundred words. Records kept by the students for five consecutive quarters indicate the average rate of writing to be about two hundred words an hour.

The reading rate, similarly obtained, is about 42 pages an hour

for non-fiction, 57 for fiction. It has been worked out for the books most commonly read, and is thus an aid in estimating final grades. As the class grows larger, the problem of obtaining a sufficient number of the requisite books has had to be met. The earlier solution, the instructor's private library, supplied only one copy of each; the small fund allowed by the library each year, although a great help, adds new books but slowly. The additional copies required are at present supplied by the students themselves, each of whom permits the use of his own book by the others while he is a member of the class. Sometimes three or four copies are found useful, in the case of such popular authors as Eddington, Chase, and Overstreet. Significant indeed is the fact that although the total number of hours to be put in by each student is only 99, for the one hundred six students of last year the average number actually spent was more than 114. When the men lose their former dread of reading, and find out for themselves the value of good books, one of the main objectives has been reached. They are expected also to have learned by the end of the course how to discover for themselves worth-while material, both literary and informational.

In a review of the English situation at the University of Washington, two factors are seen to be outstanding. One is the high degree of coöperation existing between the Head of the English Department and the Faculty of the College of Engineering, which has made possible the trying out of new procedures and the adoption of those productive of best results. The other is utilization of the student's own initiative. He is given opportunity to eliminate the minor errors hanging over from his high school days, opportunity to assimilate the principles of effective professional writing, and later opportunity to investigate for himself the fields from which he hopes for greatest gain, in which consequently he can work with some enthusiasm. The vast majority of engineering students are of good mental caliber and unswerving purpose. Once convinced that English is essential to their success as engineers and human beings, they rise to their opportunities here as in the courses purely technical. English becomes to them truly a necessary part of the engineering curriculum.

THE SELECTION OF DESIGN ENGINEERS *

By EDWIN H. BROWN

Engineer, A. O. Smith Corporation

The field of Mechanical Engineering may be viewed as one of fairly specific design and such that it generally draws into the field of specific design many who are primarily concerned with the operation of mechanical apparatus and plants. It is the intent of this paper to present a summary of one view of the different branches of design with comment on the qualities that seem most desirable in men who apply themselves to the different kinds of work.

The influence of education has been more marked in some branches than in others and a particular effort has been made to present the author's view of their influence.

The growth of industry has led to division of the functions of design engineers that have, for the purposes of this paper, been divided into three parts that have been designated:

(1) Apparatus design
(2) Plant design
(3) Design analysis.

The function of these divisions can be sub-divided into important parts for the purpose of considering the qualifications of engineers.

Apparatus design is considered as covering the field of machine design and kinematics, heat transfer apparatus and machines and apparatus that have to do with the flow of fluids, both liquid and gaseous. Those engineers engaged in what has been termed apparatus design are considered as working in or directly supervising a drawing room where designs are made from which the manufacturing or building is done; they are the staff of draftsmen.

Plant design is considered as that branch which arranges machines or groups of machines which serve as a unit into a producing plant. It includes all the important works of shop and plant arrangement and has the essential function of coördinating the work of apparatus designers with that of plant operators or the production

[1] Presented by the Machine Design Division at the annual meeting of the S. P. E. E. held at Purdue University, June 19, 1931.

staff. It also covers the field of the mechanical engineer's work in the structural design of buildings. The details of connecting apparatus frequently are part of this design work.

The term "design analysis" has been applied in this paper to the work which has become of great importance to the general administration of industries engaged in the manufacture and fabrication of engineering apparatus and also those engaged in the operation of plants where the apparatus is installed. Design analysis is considered as covering the mathematical application of the laws of thermodynamics, hydraulics and the flow of fluids, stress determinations and vibration effects from inertia forces and rotating parts to machines and plants. It frequently has placed on it the burden of determining whether a proposed machine or a process of manufacture or operation that is in accord with scientific laws is practical as a commercial art. The work of design analysis is considered also, in some of its phases, as related to the functions of engineering economics. It has also grown in one form or another to be the tie between the work of the laboratory, the development floor or shop and those engaged in apparatus and plant design.

The desirable qualities and characteristics of men engaged in the different branches of design may be generally summarized and classified for purposes of selection into a relative few divisions.

Apparatus design yields success with great ease to the man with ingenuity. If the faculty of devising ingenious parts or motions or other features is tempered by patience and persistence it seems that the man generally grows quickly out of the one subject or work he has been following.

Plant design, because of its requirement for coördinated effort can be considered as placing a premium on the qualities of attractive personality and memory. The ability to summarize concisely and observe closely seems also to be reflected in successful individuals in this work.

Design analysis apparently finds its successful men in those having a reasonable command of applied mathematical laws, the quality of studious attention to references that have been published, and originality in analytical thinking.

The influence of education on the work of selecting design engineers is important and has come to have varying weight for men in the different branches.

Apparatus design demands a knowledge of applied draftsmanship. The American university graduate generally is without great training in this subject and acquires it only by starting at the very bottom in the drafting room. It also requires mastery of the application of the formulas of mechanics, kinematics, flow of heat and

flow of fluids which is generally learned in practice and not in the classroom.

It would be of great value to apparatus design if academic training could be given in the limitations to practical success that are imposed by manufacturing processes in the steel mill, pattern shop, foundry, machine shop and fabricating or assembly plant. If it were possible to instruct the American engineering student in these practical subjects some of the aversion to work in the drafting room might be removed and his excellent training in other phases of engineering made more available for apparatus design. It may even be said that at present the general rule is that selection of men for apparatus design requires working experience, regardless of education, for any position but that of detail beginner.

Plant design is also a phase that is filled in even its detail parts by men with experience although a thorough technical education may be regarded as offsetting the importance of experience in the selection of individuals.

Design analysis seems to offer an excellent field for the technically educated man, especially those from American universities. It requires a broad type of technical knowledge as well as the ability to make specific application of formulas and the laws of nature. Its work is frequently done by technically educated men who after graduation have started their work in the laboratory, the development shop, the test floor, or in field and service engineering.

In the foregoing the author has undertaken to set down what is mainly a sub-division of engineering functions and individual qualifications that have been drawn from observation and from a limited experience in the selection of engineers for mechanical engineering design.

TECHNICAL EDUCATION AND THE INDUSTRIAL DEPRESSION

By JEROME W. HOWE

Professor of Civil Engineering, Worcester Polytechnic Institute

Munich, Germany.

In a current German engineering journal Dipl.-Ing. C. Volk contributes a plea for such measures as will adapt the courses in technical colleges to the present times of economic distress. His argument is provocative of some thought. Since students graduating from such institutions may for the next few years find it difficult to obtain positions for which their studies have prepared them, their last year at least of study should be utilized, so argues the writer, to widen their special knowledge, to increase their versatility or adaptability, and to develop in them the power to enter successfully upon vocations quite unrelated to their special training during the present partial suspension of scientific and technical activities.

If we consider the entering students, it is clear that they will presumably only to a small extent enter upon careers for which the present arrangement of courses prepare. We must therefore bring about a more free and flexible curriculum, must reduce the number of students admitted to the newer special courses, and for those who cannot be admitted to special courses suitable curricula must be carefully planned.

The higher institutions of learning must at the present time, in addition to their former tasks, take responsibility for a new and unaccustomed burden. They must act as "storehouses" of youth; and for a great number of their students, instead of preparation for a definite career, they must furnish mere useful occupation of time, or better, opportunity of study for the study's sake (discipline of habits and mental processes, presumably).

The authorities of schools of every grade and kind rest under the obligation in these times to so modify the courses of instruction, particularly in the last year of training, that the instruction will fit in large measure into the changed industrial life and will also give a certain preparation for the immediate period of unemployment in which the outgoing student will find himself.

He cites the case of one German technical college, state-supported of course, in which the numbers of both staff and students

have been reduced because of the difficulty of furnishing the accustomed financial support in these times, and he protests against the economic folly of such measures.

May one be permitted to comment briefly upon these theses?

Manifestly, education and instruction is one of the best countermeasures against idleness and its consequences in times of widespread unemployment, and every sacrifice that may be necessary on the part of tax-payers, school authorities, benefactors, and teachers themselves must be cheerfully made to keep the schools going full-blast. Present education is the surest safeguard against any possible collapse of civilization, and there are daily new pessimistic adherents to the view that a break-up of our present social and industrial structure at least is imminent.

It would be a mistake to discourage young men of proper training and aptitude from entering upon or completing technical courses because of present conditions. Whatever may come, it is difficult to conceive of such a condition that engineers will not be greatly needed and an engineering education generally useful. But the above quoted views respecting relation between special courses of training and future occupation ought to be carefully considered.

Perhaps a greater flexibility in courses is demanded by the present times. Probably fewer students should be encouraged or permitted to enter upon very specialized courses, though it would be a great mistake to abandon such specialized and advanced instruction altogether.

But in the resulting rearrangement of curricula for other students for whom a less specialized course must be prescribed, every care should be taken to avoid superficiality or aimless generality. Even if study for the study's sake is the objective which the present status of employment may in part impose, these faults may nevertheless be avoided. The fundamental subjects in the major branches of engineering are so fundamental not alone to special careers but to undertakings and activities of all sorts, that they can still properly be pursued by all students.

Mathematics, the sciences, drawing, the usual cultural studies and the basic and more elementary subjects appropriate to the several branches of engineering can then be safely continued in the curricula. With respect to the studies that are commonly pursued in the last year of the course, however, may there not be at present some desirability of a change away from the more specialized and toward the more general studies? This might take the form of additional study in the field of economics with a view to giving the graduate the best possible preparation for changed, changing, and puzzling economic conditions which he must soon face. And it may be that further prosecution of the study of mathematics and the

pure sciences would be more desirable developers of intellectual power and general ability for some types of students than further study of applied science and technology, while for other types, additional practice in handicraft and manipulation, such as is to be obtained in the courses in forge shop and metal-working, foundry, wood-working and machine shop, and electrical laboratory, may be the most promising preparation for the unpredictable occupation which will ultimately claim the student.

In view of the existing uncertain professional opportunities and requirements, it may well be that the present is an appropriate time for extensive, far-reaching experimentation in the fields of education in general, and not less in the departments of technology and engineering. And in any rearrangement of courses of instruction it should be constantly borne in mind that, respecting preparation for the immediate future, the training programs should provide for the attainment of a fair degree of widely-adaptable expertness in the common crafts and activities in which the graduating student is likely for a while to find the largest number of immediate opportunities, while for the more remote future, the best present preparation is a more thorough and extensive education in the basic courses —mathematics, science, mechanics, English and economics.

SECTIONS AND BRANCHES

Missouri Section.*—*Minutes of First Meeting.* On Friday, November 20, 1931, representatives of the engineering faculties of the University of Missouri, the Missouri School of Mines and Metallurgy, and Washington University, assembled at the Forest Park Hotel in St. Louis for a dinner meeting, presided over by Dean A. S. Langsdorf of Washington University. Following the dinner Professor A. L. Hughes of the Physics Department of Washington University presented a paper on the life and work of Michael Faraday, and Professor W. L. Upson of the Electrical Engineering Department of Washington University presented a discussion on the life and work of Joseph Henry. General discussions of both topics and of other matters of interest to engineering educators followed.

On November 21 a meeting was held at Washington University for the purpose of organizing a Missouri Section of the Society for the Promotion of Engineering Education. A list of those present is attached.

The meeting was called to order by Dean Langsdorf who after briefly outlining the steps which had led up to the calling of the meeting, asked for nominations for a permanent chairman. Dean A. S. Langsdorf of Washington University was unanimously elected chairman.

The chairman then called for nominations for a secretary. Professor H. H. Armsby of the Missouri School of Mines and Metallurgy was unanimously elected to fill this position.

The chairman appointed Professors Frame, Rubey, and Sweetser a Committee on Resolutions to prepare a resolution for forwarding to the national officers and to make recommendations to the section as to the frequency of meetings of the section.

Professor Armsby of the Missouri School of Mines and Metallurgy presented a paper embodying the results of a study of placement examinations compared to performance throughout the college course. A general discussion of the paper followed.

Professor C. V. Mann of the Missouri School of Mines and Metallurgy presented an informal discussion of the program of the committee on tests of the National Society; the program of the department of Engineering Drawing at the Missouri School of Mines and Metallurgy in testing, grading, sectioning, etc.; and the general nature and methods of construction of objective tests. A general discussion followed.

* Council has approved the formation of this Section.

The committee on resolutions reported, recommending:

First: That the number of officers be increased to three in order that there may be one officer from each institution.

Second: That the three officers constitute an executive committee for the conduct of the affairs of the section.

Third: That there be an annual meeting in the fall, the time and place to be arranged by the executive committee shortly in advance of the time of meeting.

Fourth: That a resolution be forwarded to the general officers of the Society for the Promotion of Engineering Education, petitioning them for the formation of the Missouri Section of the Society.

The first recommendation was adopted and Professor Harry Rubey of the University of Missouri was elected vice-chairman by acclamation.

The second recommendation of the committee was unanimously adopted.

The third section was amended to provide for a spring meeting when deemed advisable by the executive committee, and unanimously adopted as amended.

The fourth section of the committee report was adopted unanimously.

Professor Lanier of the University of Missouri presented the regrets of Dean McCaustland of that institution for his inability to attend the meeting and presented an invitation from the University of Missouri for the section to hold its next meeting at Columbia. The invitation was referred to the executive committee.

The meeting adjourned shortly before 1:00 P.M. to the Commons of Lee Hall where a luncheon was served, complimentary to the visiting delegates from Columbia and Rolla.

Attendance

From University of Missouri: A. C. Lanier, J. R. Lorah, Harry Rubey, M. P. Weinbach.

From Missouri School of Mines and Metallurgy: H. H. Armsby, J. B. Butler, M. H. Cagg, F. H. Frame, C. V. Mann, A. J. Miles, G. O. Ranes, I. H. Lovett.

From Washington University: T. R. Ball, F. A. Berger, G. G. Billings, B. R. Brick, A. W. Brust, F. H. Derby, R. D. Dunlap, H. R. Grummann, H. G. Hake, Arthur G. Jenning, G. W. Lamke, A. S. Langsdorf, L. McMaster, R. R. Middlemiss, E. L. Ohle, F. H. Pillsbury, C. W. Rodewald, Edmond Siroky, Eugene Stephens, Lawrence E. Stout, E. O. Sweetser, W. L. Upson, R. T. Webb, W. H. Wheeler.

H. H. Armsby,
Secretary

English in Engineering was the topic of the December meeting of the **Purdue Branch,** on Friday, December 11, 1931, 7:30 P.M. The following questions were considered:

1. Should the purpose of training in English be to develop precision of statement or persuasiveness? Are these two abilities incompatible? Does debating develop the one at the expense of the other? What is the main purpose of training in English anyway? Perhaps you think the subject is largely cultural; what is meant by the term "cultural" as so applied?

2. Does the engineering teacher insist upon a clear statement of definitions? Does the English teacher help the student to frame such definitions? If so, how? If not, why not?

3. Should the engineering student take a course in formal logic? If so, should the course be required, and should the English Department administer the course? What training in logic are the students now getting in English courses? Why not more?

4. Granted that our students may not be able to write intelligibly, can they read understandingly? What is being done to improve their effectiveness in reading? Should further efforts be made in this direction? If so, how and by whom?

H. E. HOWLAND,
Secretary

COLLEGE NOTES

Columbia University.—Following the proposal advanced by the Professional Engineers Committee on Unemployment and the Gibson Committee, engineers who are unemployed through no fault of their own are attending classes at the Columbia School of Engineering.

The number of engineers admitted is limited only by the size of the lecture halls. Each applicant must be an accredited member of the profession. There is no fee or credit attached to the courses, the men being admitted mainly to preserve their morale during the period of enforced idleness.

Thirty-five men, ranging in ages from 23 to 60, are attending the classes. Some take one course and others listen in on two or three lectures. Among the courses that they take are labor administration, chemical engineering, electrical engineering, organic chemistry, analysis of frame structures, sewage and sewage disposal, highway construction, economic geology, industrial plant designing and high speed gas engines. The library reading rooms have been opened to the new students.

Iowa State College.—Professor Wm. L. Hunter has been appointed head of the Industrial Arts Department, following the resignation of Professor Adolph Shane. Mr. Hunter graduated from the Iowa State Teachers' College in 1919, was an instructor at the State University of Iowa during 1920–1925, attended Columbia University and obtained his Master's degree in 1926, was assistant editor of Manual Arts Press in 1926–1927 and has been connected with Iowa State College since.

Professor Everett G. Livingston, A.B. Kansas State Teachers College, M.S. Iowa State College, has been appointed assistant professor of Industrial Arts.

Professor H. J. Gilkey, C.E. Oregon State College, 1911, has been appointed head of the new department of Theoretical and Applied Mechanics. Mr. Gilkey has been professor of civil engineering at the University of Colorado. He is a member of the board of consulting engineers on concrete problems in connection with the Hoover Dam. Professor Gilkey's staff consists of Instructors Vernon P. Jenson, Clarence M. McDowell and Frank E. Lightburn.

James P. McKean, who was assistant personnel officer and instructor in general engineering teaching valuation, resigned to

become valuation engineer in the securities department of the department of state, Des Moines. Jean Hempstead was appointed to take his place.

Richard Beckman, C.E. Iowa State College, has been appointed to teach engineering journalism and assist with the publication of engineering experiment station bulletins. Mr. Beckman has been on the editorial staff of Railway Age.

Mr. Harold W. Anderson has been appointed assistant professor in electrical engineering. Mr. Anderson comes from the University of Kansas where he held a similar position. He attended the Massachusetts Institute of Technology while on leave last year and received his M.S. degree.

The U. S. Department of Agriculture has established a field station here for the study of the utilization of farm wastes. At present, a continuous type retort with a capacity of one ton per hour is being erected for the study of destructive distillation of farm wastes. Mr. P. Burke Jacobs is in charge of the project and H. D. Weihe is assistant chemist.

The Civil Engineering Department at Iowa State College is making a study of stresses in building frames. A steel building frame two stories in height, one bay in width, and four bays in length has been constructed. The total height of the frame is 14 feet, the width 10 feet, and the length 30 feet.

The behavior of the structure when subjected to several different loadings, horizontal and vertical, has been studied with the idea of comparing stresses obtained by strain gauge measurement with theoretical values. It is also hoped that the experiment will furnish a basis, or bases, for making allowance for the effects of continuity in rigid frame buildings and give experimental data which will be valuable in the study of stresses in space-framework in three planes.

Roy V. Wright, President of the American Society of Mechanical Engineers, visited the engineering division on November 2. The subject of the speech he gave to an engineering convocation was, "How to Use the Engineering Societies."

University of Michigan.—The Michigan Summer Camp for surveying practice, Camp Davis, was moved from Michigan to the Jackson Hole Country in Wyoming in 1929. The new site affords open country for field work—the principal reason for leaving a forest area. The new location enjoys an almost perfect summer climate. Troublesome insects are almost unknown. The new camp has a gravity supply of soft, clear water from a nearby mountain. A modern sanitary system with hot and cold showers has been provided, also electric lights, telephone and daily mail service. An

excellent mess furnishes meals at a cost of about $5.50 per week. All students visit the Jackson Hole Country, Teton and Yellowstone National Parks and practically all of them go to and return from the camp on different highways. The wild animal life is varied and interesting. The distance from Ann Arbor is approximately 1760 miles. With the exception of about 450 miles, by way of the Lincoln Highway, hard roads may be followed. Paving operations now in progress or planned will provide pavement or oil surface throughout the entire distance. The average total cost for students during the summer of 1931 was $150. This includes the University fee, board, lodging and all travel.

BOOK REVIEWS

Readings in Industrial Psychology. By BRUCE V. MOORE AND GEORGE W. HARTMAN, of Pennsylvania State College, with an introduction by GEN. R. I. REES, of the Personnel Dept. of the American Tel. and Tel. Co. D. Appleton & Co.

To the student planning a career in the business world, this book offers a complete reference to the present knowledge of the important subject of psychology as applied to industry; and to the personnel man of any industrial company, it offers an almost indispensable source book of the latest practices in industrial relations. The book is a collection of the writings of eminent men in the field. It covers thoroughly such subjects as "Mental Tests and Placement" and "Labor Unrest and Strikes," as well as many others. As stated in the introduction, "Man power is the life of industry. These readings show how the application of this power can be made more effective."

F. L. B., JR.

A Bibliography of Bibliographies in Electrical Engineering, 1918–1929.

This compilation is the result of a coöperating effort on the part of ten technical librarians, members of the Special Libraries Association, 345 Hudson Street, New York City, who felt the need for such a tool in their daily work. By grouping together references to the recent literature in the whole field of electrical engineering, they have attempted to do for the engineer what has already been done for the physicist and chemist by similar publications. Research workers will understand the value and time-saving aid of a good bibliography as the first step in any investigation.

In the preparation of this list the literature of the past twelve years, both books and periodicals, has been carefully surveyed. More than fifty of the leading periodicals have been systematically searched, and all titles included which contain useful bibliographic material, whether in the form of footnotes, formal bibliographies, or chapter references. Over 2500 entries are listed, pointing the way to approximately 25,000 articles or books. European authorities are extensively cited, about one-third of the entries being in French or German. The arrangement is alphabetical under specific subject headings, selected according to the best current usage. Price $1.50.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

Standards of Performance. How many teachers of engineering drawing have had the somewhat annoying experience of being asked why engineering students cannot make a good drawing? Many teachers have stated frequently in answering such a question, that the files in the drafting room contain freshman drawings which are far superior in draftsmanship to the work done by these same individuals during their senior year. Why is this? Perhaps this experience is revealing: A recent examination of theses submitted for degrees in a certain institution brought to light that in every respect, *except the graphic language,* standards had been set up and insisted upon; and in all respects, *again* excepting the graphic language, these theses were admirable contributions. The reason seniors so often are poor draftsmen is because departments teaching seniors accept poor draftsmanship. These seniors have been adequately taught, they are entirely capable of doing good drafting, and when called upon to draw according to a standard they well know, departments teaching seniors will find them able to deliver.

What Have You? Since the publication of the problems in descriptive geometry, many interesting solutions have crossed the editor's desk and have been exchanged. In the December page is a problem of interest in engineering drawing. There must be others who have problems, or who have questions. A problem in each issue of this page should be of interest.

Readings. Suggested by Professor Rexford Newcomb, College of Fine and Applied Arts, University of Illinois: Babelon, E., "Manual of Oriental Antiquities," Grevel, London, 1906; Breasted, "Origins of Civilization," *Scientific Monthly,* Vol. 9, 289, 416, 561, Vol. 10, 87, 183, 249; Brangwym, F.; Sparrow, W. S., "A Book of Bridges," John Lane, New York, 1915; Cheney, Sheldon, "The New World Architecture," Longmans, Green, New York, 1930; Fleming, A. P. M.; Brocklehurst, H. J., "A History of Engineering," A. P. C. Black, London, 1925; Jones, H. S., "Companion to Roman History," Clarendon Press, Oxford, 1912; Le Corbusier, "Towards a New Architecture," Payson & Clarke, New York, 1929.